...GATION MANAGEMENT

FREDERICK HAYNES NEWELL

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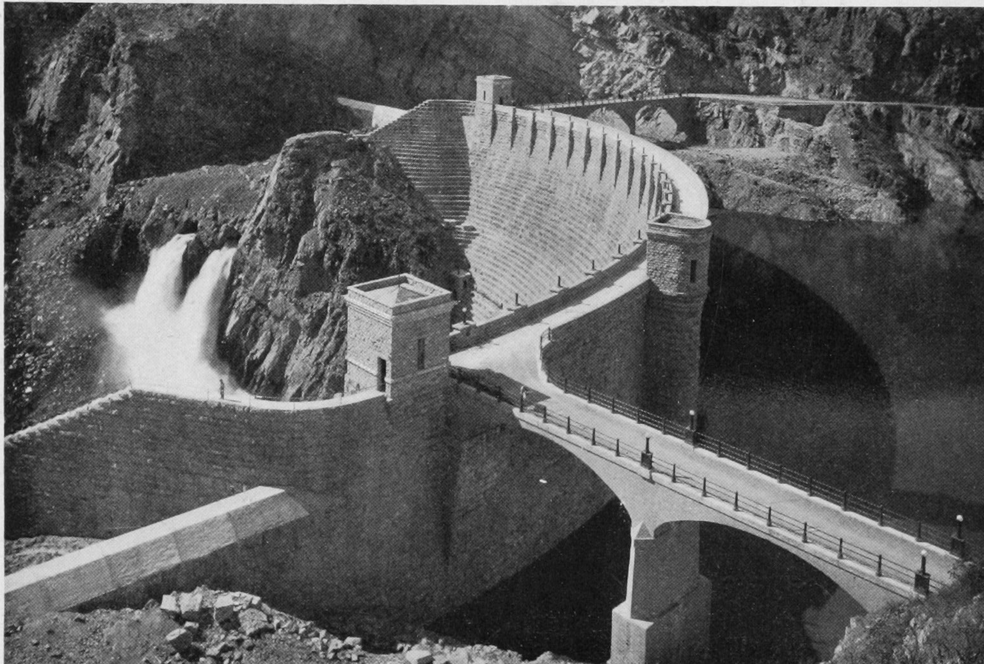

Roosevelt Dam, Arizona

One of the largest works in the United States for storing flood waters for irrigation. Dam of rubble masonry 280 feet high, 1125 feet long on top, creating a lake with area of 16,800 acres, with a capacity of 1,300,000 acre-feet.

IRRIGATION MANAGEMENT

THE OPERATION, MAINTENANCE AND BETTERMENT OF WORKS FOR BRINGING WATER TO AGRICULTURAL LANDS

BY

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PREFACE

THE irrigation manager and his assistants are coming to be appreciated more and more as important factors in the successful growth of agriculture in the western part of the United States. Within the past few years innumerable irrigating canals, big and little, have been built, bringing water to many millions of acres, In planning these enterprises the chief thought and effort of those concerned was to build works to bring water to more lands. It was assumed that, when this was done, the areas thus reclaimed would be quickly utilized and that there would rapidly grow up a prosperous and contented population. This happy condition has not followed; we are beginning to see that the planning and building of irrigation works is only the beginning; possibly it is the easiest part of the problem of conservation and use of the resources of the arid and semi-arid regions. The really difficult and at times discouraging work is that of properly utilizing the irrigation systems after they are built and of getting fair returns from the irrigated lands.

Thousands of intelligent, active men are concerned more or less directly in those operations having to do with the obtaining and distribution of water to the agricultural lands. During the past few years some of the more progressive of these men have been impressed with the necessity of getting together and talking over the problems of common interest. They have held conferences at various central points in the arid states and have met usually during the winter season to consider methods of overcoming difficulties. They have found that there is more or less similarity in the problems and that decided benefits come from the exchange of experience.

Among the leaders in this dissemination of ideas have been some of the principal men employed by the government in carrying out the terms of the Reclamation Act in the construction and operation of large irrigation systems. Twenty-five or more of these projects having been distributed throughout the various western states, there has arisen the necessity of devising more or less uniformity of method. Because of the magnitude and wide distribution of the Reclamation Works, the methods determined upon at these conferences and the precedents set by the Reclamation Service have been adopted, in more or less modified form, by the managers of large private works.

This little book is the outgrowth of these conferences as well as of many conversations, public discussions and innumerable communications from irrigation managers in public and private employ. It is an attempt to bring together in concise form the results of much of this matter and to answer many of the questions which are constantly being asked by irrigation managers, their assistants, and others connected with the works. These questions come from all parts of the world. They show that there is a growing interest in the subject and that an effort is being made to bring about a larger degree of efficiency and economy than has existed in the past.

PREFACE

The general subject of irrigation and of the methods of construction are not herein discussed, having been covered in part by previously issued books ("Irrigation," by Newell, and "Principles of Irrigation Engineering," by Newell and Murphy), to which the following pages may be considered as an appendix or a discussion from a broader standpoint. There are also now available an ever increasing number of excellent books on the details of engineering practice as applied to irrigation, the more purely technical side of the subject having attracted considerable attention.

In the preparation of statements given in the following chapters free use has been made of informal reports of the United States Reclamation Service and of ideas contained in many memoranda and letters. It has not been possible to give full credit to the original sources or to mention by name the men who have originated many of these ideas. These have rapidly passed into the body of common knowledge and have been freely appropriated by all who have considered the subject. However, particular appreciation should be expressed of the assistance rendered from time to time by Arthur P. Davis, chief engineer; F. W. Hanna, supervising engineer; D. W. Murphy, drainage engineer, upon whom the writer has called most frequently for aid, and many others connected with the Reclamation Service. To enumerate all of them would be to give a list of the working force of that organization.

Reference should be made to the "Use Book" of the Reclamation Service, which gives in more elaborate form some of the details here presented. In fact, the "Use Book" and the principal part of the present discussion were prepared at the same time, and each to a certain extent supplements the other. Many of those who have occasion to consult this volume will recognize familiar phrases or suggestions which they themselves may have made in their letters.

The early chapters of this book were prepared as separate articles and printed in substance at least in various engineering publications, notably *Engineering Record*, *Western Engineering*, *Journal of Electricity*, *Power and Gas*, *Water Power Chronicle*, and *Pacific Builder and Engineer*. The cordial reception accorded these separate articles encouraged the effort to round them out and present the ideas in consecutive and more easily accessible shape. At this time it is desired to express appreciation of the courtesy of the editors of these periodicals in permitting the use of this material in book form.

F. H. N.

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CHAPTER I

THE PROBLEMS

A PROSPEROUS, intelligent and contented rural population is essential to our national perpetuity. This is the lesson which history is teaching in all parts of the world. The opportunities for such a population are widely scattered, but are found particularly attractive in the arid regions. Under conditions of good irrigation management or water service, it is possible to attain there more nearly ideal conditions than in the humid regions where the farmer is more largely dependent upon chance in the way of adequate rainfall. It is possible by good management in an irrigated country to increase the income of the farm from two- to three-fold above that of similar land elsewhere; to double the crop on the acre while reducing the cost. The basis of this better rural life is the greater earning capacity of the irrigator over that of the ordinary farmer, due to his ability to control more largely the factors of success.

PURPOSE

The management of an irrigation system has for its purpose the delivery of water to agricultural lands at such times and in such quantities as will enable the irrigator to produce the largest and best crops. The success of the manager is measured largely by the success of the farmer. The proper management of irrigation works necessitates a skill and experience as complete as that required for a railroad system, city water-works, or a gas and electric-light system. The irrigation manager should have had years of practical experience not only in the construction of the works, but more particularly in those matters which have to do with the distributing of water to the farmers, and with the details of agricultural operations.

After an irrigation system is built or when it reaches a degree of completion where water is available for any considerable area of the land, then begin the problems of management. These continue for generations, or as long as agriculture is practiced by the use of these works. At first the difficulties are great, but, as time goes on, certain practices become fixed and the vexing questions gradually subside into routine details.

At the outset the man in charge of the operation and maintenance of the completed portions of the irrigation system is confronted with a variety of problems in the solution of which there are no well-established precedents. He must trust largely to his own judgment, and to such experience as he may have had, verified as far as possible by a knowledge of what has been done by other men. He needs to know something of the experience of others. To fill such need in part this book has been written.

EARLY TRIALS

At the initiation of the undertaking, the manager has not only his own problems of a new system and of establishing desirable precedents, but his work is greatly complicated by the fact that most of the men with whom he deals, viz., the water users, are novices unskilled in irrigation. The land has not been leveled nor made ready for economical irrigation; everyone concerned is working under the greatest of disadvantages. The irrigators as a body are not only inexperienced, but many of them are disappointed in that they have expected easier things. Thus they do not always appreciate the efforts made in their behalf. There has been attracted to the locality a considerable number of men who have never made a success elsewhere; these attribute their failure to make good under the new conditions not to their own inability, but largely to the faults of the country or of the system. Hence it happens that with the beginning of the operation and maintenance of an irrigation system, the most vexing of problems arise, and at such times there is the greatest need of patience and tact, joined with experience and skill.

PHYSICAL LIMITATIONS

The opportunites and limitations of irrigation management may be classified under two principal heads, *first* the physical, which grows out of the geographical position, character of the soil, climate, topography and water supply; and *second*, the human or social—the relation of the irrigators to each other and to the management. The physical conditions are susceptible of systematic study and the result may be accurately recorded. The human are variable and are by far more difficult, being almost unfathomable in their complexity.

As illustrating the magnitude of the physical forces with which managers must deal, attention may be called to a single one of the larger irrigation projects of the West, that in southern Arizona. This depends for its success upon the Roosevelt Dam, one of the largest masonry structures built by the United States Government. A view of this is given in the frontispiece as an introduction to irrigation management. This may be considered appropriate, not only from the magnitude of the work, but also because Theodore Roosevelt by his personal interest and devotion made possible much of the present work and opportunity of the irrigation manager.

The man who is in direct and responsible charge of a great structure of this kind must necessarily be impressed with the trust imposed upon him as guardian of the welfare of thousands of people; more than this, he must have such confidence, based upon experience, as to be able to direct without hesitation the work connected, not only with the storage of great and sudden floods which come down the river, but also the turning out of the stored water from time to time as needed, and the utilization of the water not only in agriculture upon the fields below, but in the manufacture and sale of electrical power. In short, the manager must not merely be a good business man, he must possess a wide knowledge of the various branches of engineering, embracing hydraulics and hydro-electrics, as well as the broader principles of civil engineering, in order to meet and overcome the physical complications.

HUMAN CONDITIONS

Irrigation enterprises as a rule have been considered mainly from the physical or engineering side. The promoters, more concerned with irrigation developments, have approached the subject from the standpoint of the details of building the works. They have had in mind almost exclusively those conditions which pertain to questions of cost, water supply, legal complications and related factors. It has been a matter of surprise to them to discover, after the works are built and are in condition for operation, that the real elements of success are those more dependent upon proper relations with the farmers and with the soil than those upon the works themselves. It is, of course, appreciated that for success the works must be well planned and executed, but even when this is done the owners of the irrigation system find that instead of having passed through the most difficult stage of progress, they are just entering upon it.

Closely joined with the purely human or sociological elements and relationships with the farmers are the intricate questions of agricultural practice, the relations of plant growth to water supply, temperature, and other limiting conditions.

Most of the physical conditions are practically fixed; that is to say, the works themselves when built cannot be moved or modified excepting to a limited extent. Whatever advantages or disadvantages they then possess are beyond radical modification by the management. But the biological or agricultural side, the production of plants and farm animals, the relations with the farmers, their degrees of skill, all of these are constantly fluctuating, are capable of wide modification and come within the range of the activities of the manager and his assistants either to influence directly or more often to modify indirectly.

This indirect influence which the manager can bring upon the irrigators and their success as farmers, is one of the most far-reaching and at the same time most delicate of problems. If the manager is a capable, energetic man, eager to see things move forward, he is constantly tempted to take a strong hand, with the result that he soon finds that he is practically doing the work alone. He is thinking for the community, suggesting and advising, and may suddenly awake to the fact that the energies of other individuals who might have been taking the lead in these matters are expended largely in other less useful directions. In short, he may discover that his very desire to be of assistance has resulted in demoralizing the community and depriving it of the incentive to self-help.

On the other hand, seeing clearly what should be done, if the manager has a sufficiently diplomatic turn of mind, he may be able to stimulate other men to take up these ideas as their own, so that they may push them forward with the enthusiasm which comes from belief in one's own authorship of an idea. It requires considerable self-restraint for an energetic and capable manager to keep in the background, and to see other men get the credit for initiating and leading in the progress for better things, but in the outcome it is far more important for the community that this be done than to assume or accept leadership in the activities which do not directly pertain to the management of the irrigation system.

MANAGEMENT AS A PROFESSION

The manager of a large irrigation system has as great a variety of problems as the manager of any large commercial enterprise, such as those of a railroad or of a manufacturing establishment. He must have dealings with large numbers of employees and with his customers and the public in general. There is required for success not only certain qualities of mind, such as are included under the terms "common-sense" and "tact," but also years of experience, particularly in the operation and maintenance of irrigation works.

The public or the customers with whom the irrigation manager has to deal is made up largely of farmers, men who as a rule have had little training in business affairs and who do not always appreciate the necessity of a thorough system with painstaking accuracy in detail. They are apt to ignore the requirements which in the abstract they admit are necessary for the success of the community, and which should be enforced on others, but which when applied to their individual case, puts them to some personal inconvenience. For example, if the manager does not enforce the rules regarding wasting of water to prevent the converting of roads into sloughs, the community as a whole has a justifiable criticism, while on the other hand the individual farmer who is forced to care for his waste water in the proper manner is righteously indignant at the arbitrary requirements.

There is thus involved in the management of an irrigation system the need not only of skill, but also of firmness combined with tact and rare patience to withstand the importunities which reach the manager at all hours of the day and frequently throughout the night. He rarely receives commendation, but rather the contrary, if he is zealous in protecting the interests of the community as a whole. It is this phase of the matter which renders the work peculiarly difficult and distasteful to many men otherwise well fitted for it.

Nevertheless, in spite of these disadvantages there is a certain satisfaction in overcoming the difficulties and in exercising the virtues of self-control which in time produce large results.

The manager must be constantly alert to see that he himself and his assistants are vigilant at all times, not only to observe and study the causes which may lead to discomfort or legitimate complaints on the part of the water users, but also to see to it that at all times full justice is done to the individual irrigator. In case of doubt the benefit should be resolved in favor of the man who is trying to cultivate the land. The rights and privileges of the actual settler and cultivator of the soil should be not merely respected, but guarded in his interest, and if any preference is to be shown, it is to the man who is living upon his land and endeavoring to produce crops.

The manager and his assistants, or what we may term "the Service," occupy a position of double trust in the exercise of their duties, first to operate the irrigation system impartially and in accordance with the provisions of law, for the equal benefit of all irrigators within the irrigation district, and second, for the protection of the interests of the owners, whether these be individuals, a corporation, or the government which advanced the funds with which the system was constructed. These conditions should be borne in mind constantly.

Irrigators are at all times to be treated with courtesy and respect, but every employee must remember that the organization of which he is a part serves not only the families in the immediate vicinity in which he is employed, but the whole public. Requests from landowners or other persons to irrigation service employees to act in violation of their instructions will be courteously but firmly refused, the persons making such requests being referred to the officer whose duty it is to decide the matter involved.

Irrigation service employees should always be willing to receive complaints, and should forward them for consideration to the manager or chief, in order that if an injustice is being done it may be stopped. In cases where an employee knows of a violation of duty by another employee, or of a violation of the provisions of law or of the established rules, he should report these facts. An employee's first duty is to the Service as a whole and he cannot loyally perform that duty if he allows personal interests or friendships to interfere with it in any way.

The Service should be composed of reliable and enthusiastic men, efficient, strong in teamwork, thoroughly in sympathy with the irrigator and his needs, courteous and fair in dealing with complaints and difficulties, healthy men with common-sense, who will merit the regard and secure the coöperation of all interested parties.

Need of Trained Men.—There is a demand for properly qualified men in this profession of management of irrigation systems, principally for assistants or subordinates who will enter at the bottom and gradually work their way up as the opportunity arises for them to demonstrate their ability in the Service.

In the past, most of the principal irrigation managers and their assistants have entered the profession from the engineering side, being originally connected with the construction features. They have gradually acquired experience in handling the works as they approach completion and are put into use. A large irrigation system is so complicated that at first there must be a number of men connected with the management who are thoroughly familiar with the construction of the different parts and who have had the opportunity of watching the testing out of these during the early stages. In the hundreds of miles of canals and laterals and scores of structures, there is so much of the work which is out of sight, covered up by earth, and so many points of structural weakness or possible danger, that the men or man who designed and built these portions can alone be trusted to get them into active operation. One of the greatest dangers to the new piece of work is the attempt of new men, unaware of many of the conditions, to handle it.

In the choice of irrigation managers it is not necessary nor desirable to confine the selection wholly to the engineering side. In fact, there is a need for men who have been brought up on a farm and who have had the practical experience of an irrigation farmer; especially valuable are the young men who, in addition to their life on an irrigation farm, have had a good training in the theory of agriculture at a properly equipped college. Such men, combining a little engineering experience with an agricultural course, should be the ideal assistants in the management of an irrigation system.

There is a third class of men from whom good managers have been drawn, namely, the clerical class, or the men who have come into the work as bookkeepers or accountants, who have had some experience as inspectors on the ground, and who have acquired a business training and experience which fits them to handle the larger problems of management, especially if provided with experienced engineering assistants.

There are thus three lines through which men enter the profession of irrigation management: *first*, through the engineering; *second*, through the agricultural, and *third*, through the clerical. The final success is determined more largely by the personal qualities of good judgment and tact than by the limitations of early experience along any one of these lines.

COURSES OF INSTRUCTION

The colleges devoted to instruction in agricultural and mechanical arts have given more or less attention to the elements of hydraulic engineering. Those in the arid Western states have, in outline at least, a course in irrigation engineering. The larger Eastern technical schools have also touched upon irrigation in connection with various branches of civil engineering. There has not been, however, any general recognition of irrigation management as a distinct profession for which men are to be trained by a systematic course of observation and study, but, as before stated, the irrigation managers have been the product of evolution, largely from the constructing force.

The main problems of management are so distinct from those of engineering construction that there is need of a recognition by the agricultural schools of a training for such men, one which is primarily agricultural or biological in character. The engineering problems of management, while in themselves complicated, are not as far-reaching as those having to do with the human or agricultural side of the work. They may be more safely intrusted to assistants or to occasional advice from experienced constructing engineers.

The ideal course of instruction would be one given to young men who have been brought up on the farm. This should include the theory and practice of agriculture with the elements of hydraulic engineering, and with instruction in a few of the fundamental conceptions of water laws, sufficient at least to keep the irrigation manager out of unnecessary litigation.

Correspondence Courses.—For lack of more complete training, a correspondence course in a well-established college is of considerable value and assistance to the younger men employed as canal riders or water masters and who are ambitious to perfect themselves along these lines and lay the foundation for future advancement. Such courses are now being offered in several of the western state colleges and are being followed with success by enterprising young men who could not otherwise enjoy the advantages of instruction along these lines.

EFFICIENCY AND ECONOMY

The motto of the manager of an irrigation system is "Efficiency first, then economy." Good service must be rendered; when this is done, then every possible effort should be made to maintain it in the most economical manner.

The development of an efficient system of management must come about through careful study of all surrounding conditions and experience, such as can be gained only as the works are actually operated. The details of effective service cannot be determined in advance, but must be worked out upon the ground in conformity with the requirements of each case, and of adjustment of these to laws and local regulations.

It is highly important in these matters to secure the coöperation of the water users themselves. To do this it is necessary first to work out as nearly as possible what seems to be the best system and then, having clearly in mind the requirements of the case, consult with representative water users. In other words, the management must first know what can be done and the limitations, and then make such adjustments as may be practicable to suit the ideas of the water users themselves wherever it is possible to make such adjustments within the limits of efficient operation.

USE OF TERMS

The practice of irrigation has not yet been developed to a point where there is complete agreement upon the use of terms. There is considerable divergence, especially in popular speech, as to the names applied to irrigation canals and distributaries. They are commonly referred to as "ditches" and the men locally in charge as "ditch-riders" or "ditch-tenders." With the general introduction of drainage there is thus more or less confusion, the canal being known as the "ditch" and the drain also as the "ditch" or drainage ditch.

It is desirable to adhere to some more definite usage in formal or official communications and for this reason to bring about a greater uniformity in the various terms connected with irrigation. The trunk or main water course, irrespective of its size, may properly be called the *main canal* and the larger branches known as *branch canals*. The portions of the distributing system taken out from the side of these canals are known as the *laterals* and the smaller branches as *farm laterals.*

In connection with drainage work, there are two classes of principal works, namely, open and closed drains. The word *ditch* may properly be applied to the open drains, this being in accord with the general use of the word throughout the English-speaking countries.

Manager is the term applied to the man in direct charge of the operation and maintenance, thus distinguishing him from the man previously in charge of construction work and who has been known as the "project engineer." If the system is a large one, it may be necessary to have, under the manager, two or more superintendents each in charge of a principal canal taking out usually from the opposite sides of the river. Each superintendent in turn has under him two or more watermasters or assistant superintendents in charge of principal branches of one of the main canals serving say 20,000 acres or more. In turn the assistant superintendent or watermaster has charge of the daily operations of the canal-riders, gate tenders, and laborers employed in dividing the water to the various lateral canals and in measuring it to the farmers or in maintaining the structures. (See also p. 64.)

In the Southwest the word "zanjero" is habitually applied to the canal-riders and the canal itself is called the "zanja" or "acequia." The outlet or waste way to the river is known as "desagua."

The entire organization, including the directors, the manager and his various assistants, clerical, legal or technical, the mechanics and laborers form the body known as the "Service," their highest business being to serve their employers and the public along the lines of their respective duties.

UNITS

There are two classes of units in common use in connection with water, these being dependent upon whether or not time is also considered. The quantity irrespective of time is frequently expressed in gallons. In irrigation practice the gallon is too small a unit for convenience; there are also gallons of various sizes recognized among English-speaking people. A more definite and convenient unit but one often too small for common use in irrigation is the cubic foot. In consideration of water storage, for example, in reservoirs, it is necessary to speak of millions of gallons (a million gallons equals 3.07 acre-feet) as in the case of municipal water supply or in millions of cubic feet (a million cubic feet equals 22.95 acre-feet).

The acre-foot is a more convenient unit than the gallon or cubic foot and is equivalent to a quantity of water one foot in depth covering an acre, or 43,560 cubic feet (about one-third of a million gallons). It is the unit most commonly employed in discussions of storage for irrigation and of amounts of water actually used during the irrigation season.

In Spanish-speaking countries and in Egypt the cubic meter is employed, but this is rarely known in the arid regions of the United States.

In most matters having to do with the use of water in irrigation, it is necessary to consider it not as a fixed quantity in a reservoir or tank, but as a stream flowing for so many seconds, minutes, days, or fractions of a year. The time element enters into all questions of water delivered in this form. The unit of time is the second, and the most commonly employed unit of rate of flow in English-speaking countries is the cubic foot per second, or second-foot, or, as termed in British practice in India the "cusec." This is the quantity of water delivered by a flume one foot wide and one foot deep in which the water is flowing at the average rate of one foot per second.

Throughout the West the miner's inch is in common use. This is not an absolutely fixed quantity, but is one which is dependent upon the method of measurement. It is defined by law in the different states as being a quantity which would pass through an orifice one inch square under a head of usually from 4 to 6 inches. It is apparent that the quantity of water depends upon the nature of the orifice, especially its thickness; it is also equally apparent that while 5 to 10 or even 100 miner's inches may be measured with a reasonable degree of uniformity, it is practically impossible to measure 10,000 miner's inches through an orifice on account of the difficulty of securing a uniform head above all parts of an orifice of this size. For this reason the miner's inch is now interpreted in absolute terms as being either $\frac{1}{40}$ or $\frac{1}{50}$ cubic foot per second.

There is a relatively simple relation between these two quantities, namely, that used in storage and that employed in rate of flow of water. This consists in the fact that one cubic foot per second flowing for 24 hours (or 86,400 seconds) will cover an acre (43,560 square feet) nearly two feet in depth (1.98 feet); in other words, one second-foot flowing throughout the entire day is equivalent roughly to 2 acre-feet; or to put in in another way, a reservoir or tank holding 200 acre-feet will furnish a steady flow of one cubic foot per second for 100 days.

In connection with irrigation, the development of water power is frequently desirable; there are a few simple units which may be borne in mind. For example, the electric energy of one KW (kilowatt) per hour is equivalent to one acre-foot of water raised one foot.

It is not until energy or work is performed for a definite time that it becomes measurable as power. One ampere under a pressure of 1 volt for 1 hour gives the watt-hour; 10 cubic feet per second of water under a head of 90 feet gives about 100 horse-power; which is also approximately the power necessary to heat 1 pound of water 70° Fahrenheit in 1 second. Many other examples can be cited, but these simple facts demonstrate the difference between an ampere, a volt, a watt, and a watt-hour, or in other words the difference between a quantity, a force, its energy, and its power.

Following is a list of equivalents convenient for use in hydraulic computations:

1 second-foot equals 40 Arizona or California miner's inches.

1 second-foot equals 7.48 United States gallons per second; equals 448.8 gallons per minute; equals 646,317 gallons for one day.

1 second-foot for one year covers 1 square mile 1.131 feet or 13.752 inches deep.

1 second-foot for one year equals 31,536,000 cubic feet.

1 second-foot equals about 1 acre-inch per hour.

1 second-foot for one day equals 86,400 cubic feet.

1,000,000,000 (1 United States billion) cubic feet equals 11,570 second-feet for one day.

1,000,000,000 cubic feet equals 386 second-feet for one 30-day month.

100 California miner's inches equals 18.7 United States gallons per second.

100 California miner's inches for one day equals 4.96 acre-feet.

100 United States gallons per minute equals 0.233 second-foot.

100 United States gallons per minute for one day equals 0.442 acre-foot.

1,000,000 United States gallons per day equals 1.55 second-feet.

1,000,000 United States gallons equals 3.07 acre-feet.

1,000,000 cubic feet equals 22.95 acre-feet.

1 acre-foot equals 325,850 gallons.

1 inch deep on 1 square mile equals 2,323,200 cubic feet.

1 inch deep on 1 square mile equals 0.0737 second-foot per year.

1 foot equals 0.3048 meter.

1 mile equals 1.60935 kilometers.

1 mile equals 5280 feet.

1 acre equals 0.4047 hectare.

1 acre equals 43,560 square feet.

1 acre equals 209 feet square, nearly.

1 square mile equals 2.59 square kilometers.

1 cubic foot equals 0.0283 cubic meter.

1 cubic foot of water weighs 62.5 pounds.

1 cubic meter per minute equals 0.5886 second-foot.

1 horse-power equals 550 foot-pounds per second.

1 horse-power equals 76.0 kilogram-meters per second.

1 horse-power equals 746 watts.

1 horse-power equals 1 second-foot falling 8.80 feet.

$1\frac{1}{3}$ horse-power equals about 1 kilowatt.

To calculate water power quickly: $\frac{\text{Sec.-ft.} \times \text{fall in feet}}{11} = \text{net}$ horse-power on water wheel realizing 80 per cent. of theoretical power.

CHAPTER II

THE PHYSICAL CONDITIONS

THE irrigation manager has before him certain works more or less completed, with location fixed and with a population of water users or customers provided. Unlike the constructing engineer, he does not have a free hand in planning and locating the works nor in radically modifying them to suit his ideals. He must take what he finds and adapt his methods largely to the existing physical conditions. For this reason, it is of the highest importance that he acquire a full knowledge of these conditions and maintain accurate records, not depending upon hearsay or upon assumptions as to the facts of water supply, climate, soils, and related natural phenomena; he should endeavor to initiate and keep up such observations as will increase his knowledge of the environment.

ENVIRONMENT

The methods of operation which are suitable to an irrigation system, for example, in southern Arizona, where water is delivered throughout the year, would obviously not be applicable in Montana, where the crop season is short and where the extreme cold materially affects the stability of hydraulic structures. While there are certain broad principles which can be applied under all known conditions, yet the practical application of these must be controlled from time to time in accordance with the knowledge of limiting conditions acquired by observation and experience.

The principal limitations are those of water supply, climate, and soil conditions. The water supply is perhaps the most important, as the methods of management must be adapted to the amount of water available. For example, even though the irrigation season may be so long that with ample water two or more crops might be raised each year, yet with restricted supply, it is necessary to concentrate all efforts on using this supply in the most advantageous way during the period when it occurs.

With higher development it may be possible to regulate the water supply by means of reservoirs similar to the Roosevelt Dam, Arizona, to insure a certain amount for use at any desired time. In few instances, however, is it possible completely to regulate the supply. Usually in some part of the year or during an occasional year, there will be a surplus which may be used to advantage on a quick annual crop. Thus, the ideal scheme which could be laid out under the assumption that water can be had whenever needed must be modified to produce the most effective results with fluctuating quantity.

Climate.—The climatic conditions of any locality may be regarded as fixed within a certain range. Observations continued throughout a period of half a century show that there is little, if any, progressive change, but that the average temperature, precipitation, wind movement, and other phenomena for any half-century are practically the same as that of an equivalent time preceding or succeeding this period.

The difficulties which the irrigation manager encounters in regard to climate, however, are those which arise from lack of knowledge as to what are the fixed limits within which these climatic factors vary. Throughout the greater part of the arid region the land had been settled for so short a time that there are no reliable results based on continuous observations within the particular area with which he is concerned. Usually, he can obtain the facts for four or five years, but these years for which data are had may be exceptional as regards either heat or cold, drought or storm. They may tend to mislead the manager rather than assist. However, he must utilize such facts as he can obtain and supplement these from day to day by records which will serve as a guide in the future.

In particular, there should be maintained observations of rain and snowfall at certain permanent points, such as at the principal storage or diversion dams, and at or near canal-rider's houses in the irrigated lands. Also there should be available observations of temperature to ascertain the warm or cold spots on the project and the time of occurrence of early and late frosts within the cultivated area. There are certain localities in each large irrigated district which are particularly favored in regard to temperature, and the effective distribution of water is modified by the ability of these areas to produce certain classes of crops.

The form on page 23 has been found to be convenient for keeping such records, being much simplified from those prepared by the Weather Bureau. In cases where the Weather Bureau records are kept on a project, the data from these should be had by the manager, but these usually pertain to only one point. They should be supplemented by simple records kept at various points within the agricultural area, as above noted, and also as far as practicable at the reservoir dams or other points accessible in the mountains.

A study of records which have been kept for many years reveals a tendency towards periodic variations in the weather conditions, extending through five or ten years or more. It is well known that wet and dry years occur in groups. Although an extremely wet year may succeed an extremely dry one, or vice versa, the tendency towards cycle or secular variations is very evident. This phenomenon has an important bearing on the question of water supply, chiefly because facts and data are often arrayed against the memory of the oldest inhabitant to establish or refute a theory of this nature.

There is an almost universal belief that the climate is changing; that floods and drought, heat and cold are all "different than they used to be." No matter where one goes, the same statement is heard.

It is a perfectly natural conclusion and results from two causes, one psychological, the other physical. As we grow older, our perspective undergoes an adjustment. We only retain impressions of those things that are associated in our memory with particular circumstances. "Man marks where he hits, but never marks when he misses." We recall wading snowdrifts to school. To-day those snowdrifts do not seem so deep and we immediately conclude that they are not. The water in the "old swimming-hole" was much deeper when we were boys; to-day it is only waist-deep and we think the river is smaller than it used to be. We visit a spring, after a lapse of years, from which we drank when boys; it doesn't seem so large nor the water so fine as then. The spring is

WEATHER CONDITIONS

PROJECT............ STATION............ YEAR............ ....

Month.	Temperature, Deg. F.			Precipitation.			Evaporation (inches).	Total Wind Movement (miles).	Sky. Number of Days.		
	Max.	Min.	Mean.	Total (ins.)	Greatest 24-hour. Amt. (ins.).	Greatest 24-hour. Date.			Clear.	Part cloudy.	Cloudy.
Jan.											
Feb.											
March											
April											
May											
June											
July											
Aug.											
Sept.											
Oct.											
Nov.											
Dec.											
Total & mean											

Dates of last killing frost in spring........................ of first killing frost in fall..........................

Dates of serious rainfall............., of hail storms........................, of wind storms......................

Remarks...

the same, but our conception of it has changed. Our memory of it is fixed by some isolated circumstance connected with it, while to-day we view it in the abstract, unconsciously comparing it with others we have seen since. A man's memory of high and low stages of rivers alongside of which he has always lived is invariably governed by isolated circumstances and incidents which he does not remember consecutively. For this reason such evidence is always untrustworthy, and only those who have had occasion to gather evidences of this kind know how conflicting and untrustworthy they are.

The second and principal reason for the universal belief that physical phenomena are changing is that they are actually undergoing continued changes, not, however, to the degree nor in the manner that is popularly believed. Rainfall, temperatures, humidity, winds, and consequently the stages of rivers and lakes, occur and recur with variable length and intensity. The major cycles are longer than the life of an average man—at least longer than his faculty for accurate recollections.[1]

These cycles of wet and dry years have been the subject of long-continued studies by various men in many countries. There is a peculiar fascination about them, increased by the illusive character of the data. Some men, after a lifetime of research, have proved, to their own satisfaction at least, that these cycles coincide with the appearance of the sun spots; others that they have a duration of seventeen years; others claim eleven-year or seven-year periodicity; and so on, apparently no two authorities being in accord as to the full interpretation of the fragmentary facts.

Soil.—The character and condition of the soil, while

[1] J. C. Stevens, in *Journal of Electricity, Power and Gas,* Feb. 21, 1914, p. 166.

vital to the success of agriculture, are relatively of less importance in the success of an irrigation project than are some of the other physical limitations, such as proper location of the works and favorable climate. This is because throughout the arid region the soils as a rule, while deficient in humus, are of such character that even at first, with proper treatment, they will produce fair grain crops, such as barley or wheat, or potatoes, as shown in the illustration facing page 34. Later, with careful handling, they can be brought up to a high degree of fertility. As a rule, they have not been leached of the valuable mineral salts to the same degree as the soils of the humid region. They contain considerable quantities of soluble minerals of some value to plant life. With adequate supply of water and favorable climatic conditions, the ordinary soils can usually be depended upon from the outset to produce remunerative crops.

The fact that there are certain soluble salts in the soil is not only a source of profit, but also of danger in that, by careless handling of the water, these salts may be washed out from one portion of the field and concentrated in another, producing what is commonly known as alkali, destructive to valuable plant life. With indifferent handling of the water, therefore, not only is the soil value greatly reduced, but large areas of otherwise fertile soil are more or less permanently injured and can be relieved only by an effective system of drains.

The soil of the arid region, as above noted, is usually deficient in humus or nitrogenous matter; one of the first and greatest problems of the irrigation manager on a new project is to induce the irrigators to cultivate crops such as alfalfa and peas, which will put nitrogen in the soil, and to bring about an appreciation on the part of the farmers of the desirability of plowing under some of these green crops in order to maintain or increase the soil fertility.

An unfortunate fallacy has prevailed throughout the country to the effect that irrigated land needs little or no artificial fertilizer. This has been based on erroneous statements regarding the fertility of irrigated lands of Egypt, where it has been alleged that for centuries certain fields have been irrigated and cultivated, depending wholly upon the muddy waters of the Nile. As a matter of fact, however, the men who have cultivated these fields for generations have applied fertilizer as far as lay within their power; one of the great problems now concerning the agriculturists of the valley of the Nile and other similar irrigated regions is to obtain sufficient potash and other ingredients to keep up the crop yield. (See also p. 130.)

Water Supply.—Under few, if any, irrigation systems, even where storage reservoirs are provided, is there complete or reliable information concerning the fluctuations of water supply. Each year occurs a new combination of conditions and new problems regarding the handling of the water available. Either the floods come very early or late, or are exceptionally large, or small; the average year never occurs. Thus, the manager, to have a basis for his judgment, must continually observe and record the daily changing conditions of water supply and compare these with what has happened during previous years. In this way alone can he plan effectively to use the water available.

An irrigation system usually is developed to a point where all of the ordinary water supply is needed. Then it becomes a matter of skill and judgment to determine to what extent cultivation of additional fields may be justified by the probability of obtaining more water, or at more favorable time than in some preceding year.

COMPARISON OF SYSTEMS

In order to make comparisons of irrigation systems, it is necessary to classify them in a general way; that is to say, the figures showing expenditures, for example, for operation and maintenance of a system provided with reservoirs, cannot well be compared with those for another system without reservoirs. In order to make such a comparison, it is therefore desirrable to classify expenditures for the different parts of a system, namely, for the storage or diversion of water, for its carriage, for distribution to the field, and for drainage. (See Chapter X, p. 166.) By this means the cost of a small system which consists essentially of distributing canals may be compared with the similar cost of operating and maintaining an approximately equal area or portion of the distributing system of a large canal, since this process eliminates from the comparison the cost of reservoirs and related expenditures not encountered in the case of the small canal.

STRUCTURAL RESTRICTIONS

Many irrigation systems have been planned and built by men who have had little or no experience in the practical problems of operation and maintenance. This is due to the fact that the management of irrigation systems is relatively a new art, in which the fundamental principles have hardly yet been recognized or agreed upon. Most of the systems after construction have been handled for a time by some one or another of the men connected with their construction, or turned over to local associations who have shifted the management from year to year with little continuity of plan or personnel. Thus, it happens that the man or men who may have acquired valuable experience in the practical details of managing the canal system have drifted off into other occupations.

As a result of the fact that the experience had in handling one canal system has rarely been used in constructing another, it is found that when the new system has been built and is being put into operation, there are many limitations which have been imposed by construction and which can be removed, if at all, only in part and quite slowly. For example, many of the structures may have been built with the assumption that a small, steady flow of water would be used, whereas after some years of experimentation it may be found that greater efficiency could be obtained by using large heads or runs, but that this is prevented by certain flumes or gates being too small to accommodate these large heads. (See Chapter XIII, and illustration facing page 90.) In the course of time some of these structures can be replaced and the system gradually improved. The danger is that in the meantime the water users may have become fixed in poor practices.

The irrigation manager thus has a continual problem before him of ascertaining what are the best methods and in studying how far he can put these methods into practice with the limitations which have been imposed by the men who preceded him in building the system.

He can rarely make radical changes, but must lay out a systematic course of procedure and gradually adjust the methods and works to these.

Location of Canal.—The principal restriction is that imposed by the main canal. It can carry only a certain amount of water and if there is ample supply in the river, the question of development of the project rests at first on the capacity of this canal and of its structures. The location, however, may limit the area of land which can be covered by gravity, for if all of the land which lies below the canal is irrigated, then any extension of the system must presumably be made by pumping to a slightly higher ground not commanded by the gravity flow.

Whether or not more land can be brought under irrigation by enlarging or extending the system, it is the duty of the manager at all times to endeavor to attain the highest efficiency and economy. This can be done only when all of the land which can be irrigated is put to its highest use. For one reason, the overhead charges are usually fixed, whether the area irrigated is larger or smaller or the crop production greater or less; thus every additional acre of land which can be served tends to reduce the proportionate cost per acre to the irrigator. While there are these limitations imposed by the original size and location of the main canal, it is usually possible to increase the effective area by careful study of surrounding conditions, particularly as to the practicability of pumping water at drops in the main canal, and of distributing it more completely to the lands within the reach of gravity.

In reviewing the physical conditions and limitations which are imposed upon the manager of any large irrigation work, it is appreciated that from the physical standpoint he does not have the breadth of opportunity in molding and shaping conditions that his brother engineer has who is building similar works. Nevertheless, although these physical limitations do set relatively narrow bounds, there is opportunity for the exercise of the engineering skill, judgment and ability in dealing with the problems of making the works serve their highest purposes in bringing water to the land at the right time and in the quantities needed by the soil. There is always opportunity for the exercise of ingenuity in fitting the canal structures more closely to the limitations. The continual study of these problems yields many interesting facts, some of which previously had been overlooked or which have developed as more complete knowledge is had of the climate, soil, and water supply.

CHAPTER III

THE HUMAN ELEMENT

THE engineer who has graduated from the construction of an irrigation system to the management of it, finds that his principal problems are quite different from those which he encountered during the construction period. The human element comes to the front; while the physical difficulties, though not small, sink into relative insignificance when compared with those which grow out of the dealings with hundreds or even thousands of individual water users who are to a certain degree proprietors of the works. For success the manager must be something of a diplomat and have a keen insight into the motives of individuals and of masses of men. He stands almost in the position of Providence in dispensing life-giving moisture and at the same time must be the agent or representative of the financial interests which have built the works.

Pioneers.—The men who built the first irrigation canals in the arid West were typical pioneers, forced by necessity to endure hardships, with their ranks thinned and the average raised from time to time by the elimination of the weaker or less fit members. They came into the new and almost unknown country one or two at a time, or in little groups, bound together by ties of relationship or common danger. They learned to work together, to practice coöperation in irrigation, and gradually built up irrigation systems of considerable size and intricacy.

The modern pioneer is of a different type. He is attracted usually by glowing accounts of the relative ease of acquiring wealth in the West, and with erroneous ideas concerning the conditions to be met. He has been allured by the advertisements of land companies or of railroads interested primarily in the profits from homeseekers' tickets or from the freight rates on their household goods, and ultimately on the materials which they may produce.

The widespread advertising with gorgeous lithographs naturally tempts the more restless individuals of the community, especially the men who have not made good at home. There has thus arisen a class which has been called the "professional pioneer," always seeking for something a little better or for conditions where life will be easier; staying in any one locality only a few months or years and then again seeking El Dorado.

Selecting the Farmer.--The success of an irrigation enterprise is more dependent upon obtaining speedily the right kind of farmers than it is upon the completeness of the construction and the adequacy of the water supply. This fact is generally overlooked; while skill and care have been shown in the selection of the project, in the determination of the amount of water which may be available, in the drawing of engineering plans, in the securing of all of the legal conditions and qualifications, and the safeguarding of all of the physical features of the work, yet at the same time there has been a general neglect of the more important item of the choice of the farmer or the selection of the men who will utilize these works and make them a success.

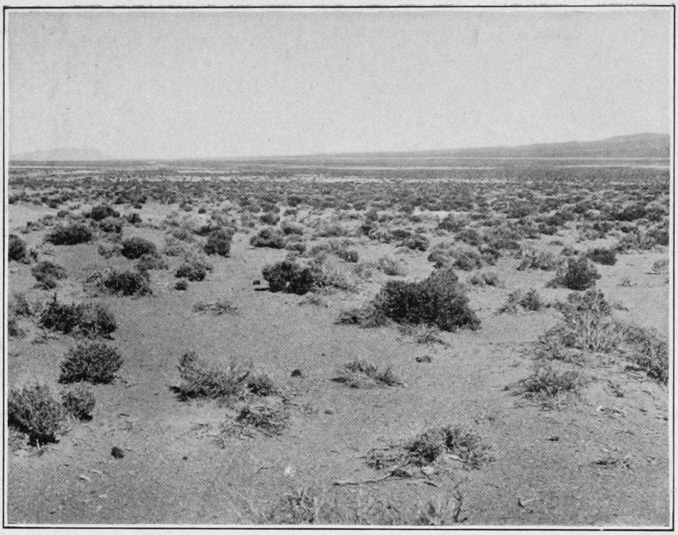
It has been assumed too often in the past that any man can take a piece of raw land, or even an area that has been partly subdued, build a home, start the cultivation of crops, choose the best kinds and arrange to market these in a remunerative manner. As a matter of fact, this is the weak point of the whole irrigation proposition. It is as though a high-priced, complicated machine, such as the automobile, were put at once into the hands of the first man who applied, and the safety of the machine and its occupants trusted to a man whose skill had never been fully shown. So it is with the newcomers on an irrigation project. About the only test which is applied is that of the financial ability of the man to make his first payment. In some cases this first payment is extremely small and there is practically no proof to indicate whether the applicant for an irrigated farm is really competent to undertake the business.

The results are as should have been expected. Many of the would-be farmers are in no way suited for the work and when it is made evident that they cannot make a success, there is no way by which they can be immediately placed elsewhere and an opportunity afforded to some other man who has the ability to make use of it. It is much as though a large factory had been built equipped with modern machinery and the applicants were then allowed to select their own machine or occupation, and it was incumbent upon the management to do the best possible with the people who came without knowledge of the processes, but who had been attracted by the outward appearance of one particular machine or another. The success of any such enterprise must obviously rest not only upon the adaptation of the machine to the work, but of the people to the machine and to the work.

In the case of large private enterprise, it is often possible to a certain degree to select at the outset the class of settlers, or at least to hold the land until the man who seems to have suitable qualifications arrives, but in the case of government enterprises, this condition is impossible and the man who has not the qualities to make a successful farmer, has not the strength, the perseverance, the thrift, or good judgment, must be permitted to select a farm if one is available and to work out his own problems. He may perhaps consume years in wasted efforts in his own life and incidentally waste the investment of others before it is possible to get him to give way to some man better equipped.

Time Needed for Settlement.—An agricultural community cannot immediately be placed upon a successful and permanent basis. Years are required for a body of farmers to establish social or business relations and get into the condition commonly known in other industries as a "going concern." In the case of a large manufacturing institution, it is possible to erect buildings within a few months, assemble workmen, and organize the operations so that in the course of a few months the larger features are well under way; this cannot be done with farming. It is the failure to recognize this condition which has led to most of the disappointments and financial failures in irrigation enterprises.

Studies of the settlers on various projects show that upwards of 75 per cent. of the first-comers or pioneers have left within the first three or four years. This is naturally to be expected, as the first-comers were usually the more restless members of a community, men who



The Desert before Irrigation.
Sparse vegetation and apparently sandy and lifeless soil.

The Desert after Water has been Applied.
Furrow irrigation of potato field near Powell, Wyoming.

were always on the lookout for something new and when they had discovered it were anxious to dispose of their acquisitions and move on to a still better opportunity.

Lack of Experience.—Few of the persons who come into an irrigated region have had experience under the conditions similar to those encountered in the new home. Even if they have practiced agriculture by irrigation before, the experience thus attained may not be applicable under the new conditions. Knowing little of the difficulties to be encountered, the new-comer, if he takes advice at all, is inclined to seek it from his neighbors, many of whom are little qualified to give sound advice; he is as apt to imitate bad practices as good ones. The kind of experience that is needed for success under new conditions is not appreciated at first and frequently those things which should be done, as shown by later developments, are neglected because they appear too difficult at the start. The item which is most habitually neglected is that of careful preparation of the surface of the land for irrigation. During the first year or two the farmer is so busy with building his fences and needed shelter for himself and animals, and in getting in his crop that he is forced to skim over the surface rather rapidly, and having once tilled the soil he is inclined to leave it somewhat rough or rolling. The best farmers, however, if they do not have time during the first year to level properly all of their fields, make a practice of thoroughly preparing each year a few acres. For example, on a forty-acre farm especial attention may be given the first year to leveling off five acres, and the next year this area is extended. Thus, in the course of a few years the surface of the entire farm is brought into condition for the highest economy in time and labor in applying water and with consequent reduction of the amount of water applied and larger crop yields.

Need of Capital.—One of the greatest needs in developing any country is the possession of ample capital. To acquire a "going business" in agriculture under irrigation is relatively a difficult, slow and expensive enterprise; one which requires a considerable investment in tools, farm animals, and seed, as well as in house, stable, and fences. The new-comers, as a rule, do not have enough money to equip themselves for the work in hand, and often do not utilize the money which they do have to the best effect for producing large results.

Some of them had more than the average amount of money when they came into the country, but they made the mistake of buying too much land or machinery. For example, one man came to a new project with over $7,500 cash and a somewhat expensive family. Instead of confining his outlay to 40 acres of good land, he bought 160 acres and paid down $5,000, putting most of the rest into a house, barn, and implements. He had literally nothing to live upon after he had made this investment; he found to his sorrow that he could not again sell any of the land he had bought at prices which he had already paid. A neighbor coming in with less money and confining his efforts to 40 acres made good. It is not the possession of ample funds which insures success, but rather ample brains and experience, with a moderate amount of cash.

Incompetents.—There are naturally attracted to all of these new opportunities a considerable number of persons who have not only made a failure elsewhere, but are wholly unfitted through lack of physical or mental strength of achieving success even under the best conditions. Thus, there is apt to be in these new communities a larger proportion of unfit persons than in the older settled communities.

It frequently occurs that irrigation is attempted by men who are not able to make a success of ordinary agriculture, but who have faith that they can carry on this more difficult task with success, although they have failed in the easier operation of farming under humid conditions.

One of the greatest discouragements in operation and maintenance is the presence of many of this class of men, some of whom have taken up lands in the most conspicuous localities. While the percentage of these may be small, yet there are enough to create an unfavorable reputation for the project. As one old farmer expressed it: "We have too many of these do-less fellows. If you gave them 160 acres with complete rights, they would be unable to make a living. The lands look like a 'widder' woman's place."

The competent men, those who have enthusiasm, energy, and a reasonable amount of skill and capital, gradually replace these "do-less" men, and coming to the project after the first rush is over or during the progress of the developments, are usually able to purchase or obtain a small tract of partly developed land at reasonable expense, to this extent possibly profiting at the cost of their less fortunate predecessors. (See illustration facing page 90.)

Shifting of Population.—The men first attracted to a new country rarely find life there as attractive as they had hoped. Some are easily drawn away again by the allurements of other lands which are being opened. They belong to the type of adventurer seeking something better. After a man of this class has been a year or so on an irrigation project he usually succeeds in trading off his property, and during the first five years as many as three families in succession may have been established upon any one of the irrigated farms.

Because of this rapid shifting of population, permanent development does not proceed with as great rapidity as anticipated and the irrigation manager is balked in his efforts at bringing about a better cultivation of the soil, notably because many of the original entrymen upon the irrigation projects were without financial means, while others living in nearby towns attempted to conduct some business in town and run the farm as a side issue. These persons quickly found that this was impracticable. Farming requires all of the ordinary man's time and energy, and few men can successfully carry on two distinct classes of business.

Community Coöperation.—Under earlier pioneer conditions in irrigation development, there was a spirit of coöperation in the community, due to the fact that the people settling together along a stream in the arid region were usually bound together by ties of friendship of former neighborhood association. The common difficulties and dangers brought about a high degree of mutual protection and the communities in which some effective coöperation did not exist were soon wiped out.

The small irrigation canals were those built by this coöperative effort and were thus operated, success depending upon mutual support and assistance. There also grew up the development of community methods of handling products and coöperation in marketing them.

In the cases where irrigation works are built by corporations or by the government, and settlers are attracted from all parts of the earth, the same degree of community life is not possible at the outset. The result has been a more complete individualism, which, beneficial in some ways, has been injurious in others. Under the older systems it was usual for the community to appoint its own watermaster, who saw to it that water was turned to the fields of the various owners. Under the larger corporate system, however, the farmers on an irrigation lateral are not neighbors in the full sense of the term. They do not have the same interest in each other's success and it has rarely been possible for them to join together in distributing water fairly among themselves. It may take a generation for them to learn those lessons of mutual respect and forbearance in water distribution which the pioneers were forced to adopt in face of failure.

From this it results that in the large irrigation systems built by private capital or by the Government, the method of distribution of water must be entirely different from that practiced by the coöperative irrigators. The water must be taken to each man's farm, because if left to be distributed among a small group, there is always complaint that the man at the end of the lateral, or the weaker member of the community, does not get his share. It is necessary to have some one strong central authority to whom this man can appeal for protection against the propensities of his neighbors to take his share of the water.

Success is Gradual.—The farmers as a whole attain a slow but gradual increase in the value of their farms and products in spite of the frequent changes and failures which appear on the surface. They begin with land which has little, if any, real value beyond the expense incurred in bringing water to it. They make this land produce crops which in the course of a few years create the basis for a permanent income. As before stated, the crop yield and its market value fluctuate within wide limits, the years of scanty production and good prices being followed by larger crop yield and low prices. These oscillate backward and forward with more or less regularity, but constantly make steady upward growth.

It is desirable to have from time to time an inventory or taking account of stock of the real conditions to make apparent the fact that there is this gradual increase in true values. Otherwise there is apt to be discouragement because of the fact that one year did not appear to be as profitable as the preceding. While this may be the case for any particular year or locality, yet taking the whole body of farmers, it will be found that they have advanced materially during four or five years.

From the conditions before stated, of time required to settle a project, the shifting of the settlers and lack of capital, it necessarily happened that there has been complaint of irrigation in general, also of the climate and country, and particularly of the men who built the works, and are operating them. The latter, being on the ground, are the visible evidences of an organization or institution which induced or permitted settlement, and naturally are held immediately responsible for all failures.

It is the duty of the project manager and his assistants to study fairly and impartially the needs of the settlers and to meet their needs as far as practicable.

As a result of study of many score of individual cases, it is found that most unfavorable reports come from men who are not actually living on their farms and cultivating them, but who regard farming as a sort of secondary occupation. They are the men, for example, who live in town and try to make a living through the practice of some trade or profession.

The real farmer, who is devoting his entire thoughts and energies to his farm, rarely has time to complain even if he has cause, and is usually too independent to air his grief. On the other hand, the type of man who spends most of his time at the corner grocery is full of dissatisfaction with the weather, the country, the crops, the railroads, and all other factors, and usually takes sufficient time to make this fully known throughout the community.

The great majority of the farmers on any well-established project are and must be active, conscientious, hard-working men. They and their families are undertaking a work which although primarily for their own support, indirectly is of the highest value to the country. They are entitled to great consideration and respect, and even though this were not required by ordinary courtesy among men, it would be by the fact that they belong to the class who are the mainstay of free institutions.

Encouragement of New Men.—A most important detail of the work of the irrigation manager is that of giving proper encouragement to the homeseekers or to the new men on the project, avoiding on the one hand excessive optimism, which ultimately must lead to discouragement, and on the other the pessimistic attitude which points out only the difficulties and failures which have followed. Considerable tact and patience are required in this, as the average farmer or settler has a vague conception of irrigation and is largely ignorant of the difficulties connected with the handling of the water. Thus, he is apt to go to one extreme or the other in assuming that the application of the water is a matter requiring extraordinary labor or skill, or that it consists merely in opening a gate and letting the water flow to the land, while he is busy elsewhere or is sitting under a tree watching it flow.

Experience has shown that much of the cause of misapprehension on a project can be removed if the project manager or his principal assistant can take the time to visit the individual irrigator on his farm, particularly in the case of a new man who is not yet accustomed to his surroundings. It is highly important that the project manager shall lay out his own work so that this can be done and that he may be personally acquainted on the ground. Public meetings or conferences will not accomplish this, as at such meetings it is rarely possible to have the true conditions, properly developed; nor can this be done as well in the project office as at the home of the settler. There his confidence may be more quickly gained as well as a first-hand knowledge of his needs. An examination of the difficulties on the ground enables an experienced manager to adjust innumerable little matters which in time might become aggravating.

Diffusing Information.—Every reasonable effort should be made by the irrigation manager and his assistants to remove all just cause for criticism and to furnish information, such as will relieve all misapprehension of the facts. Emphasis should be placed upon civility of manner in answering questions, even though the question itself may not be wholly pertinent or intelligible. The employees of an irrigation service should try to maintain a high standard of courtesy in this regard, even under exasperating conditions. It should be borne in mind that the average farmer does not understand the more or less technical phrases with reference to the measurement and flow of water, and has less knowledge of the fundamentals of land and water laws.

Many of the questions asked are those which cannot be answered fully by any person in the field, as they relate frequently to laws and decisions. In such cases, if the question is apparently asked in good faith and is not merely the result of idle curiosity, the questioner should be asked to write out the question, so that he may state the necessary facts, and send the question directly to the central office. It must be borne in mind that many such questions relate to conditions which have not yet been decided and it is not possible in all cases to give a definite reply until the particular case has been passed upon.

Often the inquiries are not put in such form as to be wholly intelligible, nor is the spirit in which they are asked one which is conducive to a frank discussion. Not every well-disposed farmer is blessed with such equanimity that he does not become annoyed at what seem to him to be unreasonable requirements of law or of regulation regarding the distribution of water. The questions he asks are sometimes put in an offensive manner. The attempt should be made, however, to treat the question as put in good faith and to try to give a reply, showing clearly that the matter in hand is not one which is within the power of the local man to answer, avoiding at the same time argument and confining the reply to a courteous presentation of the fact that such matters are outside of the province of the irrigation manager.

The manner of reply should always be that indicating an interest on the part of the employees in the welfare of the individual making the inquiry and of the project as a whole. The "don't care" style of conversation should be avoided. Sometimes a simple explanation volunteered in the proper spirit will suffice to clarify matters; a "soft answer" on the part of an employee even to a farmer who may seem to be of the most refractory kind may chance to "turn away wrath" and make more effective the work of the organization.

In the operation of all large machinery, whether composed of metal or of men, there must be the use of a proper amount of lubricating material to prevent heating of the bearings. In the transaction of ordinary business it has been found that the use of courteous phrases and self-control, the avoidance of argument, are the lubricants which enable large business to be transacted rapidly and smoothly. In short, courtesy is as necessary in the points of contact in an organization as oil is in the bearings of a steam-shovel or automobile.

It is highly important that the manager of a project have such knowledge or appreciation of agriculture that his attitude toward the farmers is sympathetic. At the same time this sympathy with the farmers' troubles should not be confused with weakness, as the successful manager must display a firmness of purpose to a degree rarely called upon in other occupations. In choosing his assistants he must exercise great care, as a tactless or careless canal-rider may work infinite mischief. At the same time the manager, while appreciative of the difficulties of farming, must hold fast to the underlying principles of water distribution and not be guilty of conceding where such concession is opposed to sound policy.

CHAPTER IV

THE LEGAL ASPECT

THE engineer or business man who is placed in responsible charge of an irrigation project has not only many duties connected with the purely physical side of maintaining the works and of distributing the water, but also he has dealings with hundreds of individuals. Growing out of these relations are almost innumerable matters pertaining to legal requirements; the manager must continually exercise discretion in answering questions of mixed legal and physical fact.

Importance of General Knowledge.—While it is not expected that the manager should be a lawyer, yet he must know enough of the fundamental principles of water laws, at least, to be able to state these clearly and to avoid litigation, especially over trivial matters. There is a saying in the irrigated West that "water is worse than whisky in making trouble." There is also another phrase, that of "winter friendship," implying that during the crop season every man is at warfare with his neighbor, and it is only after the crop season is over that friendly relations are reëstablished. This condition arises from the fact that the water laws in some of the states are quite imperfect, being unsuited to the needs of the people. There are few states in the arid West in which there has been provided a well-considered and logical body of legislation and machinery for its enforcement. Many of the laws are the results of court decisions, each of these arising usually from some peculiar case. Thus they have often been apparently contradictory and inapplicable to ordinary affairs.

There are certain well-established fundamentals, however, which should be recognized in every irrigated region, namely, those pertaining to the right to appropriate and take water from a stream, also the superiority of prior appropriations and the limitation of all appropriations to beneficial use.

In any general statement, it is, of course, impossible to cover the intricacies of the subject and in fact it is desirable to keep out of these and to try to obtain a broad view of some of those matters which are fundamental in the management of projects of various kinds. In the following pages these are touched upon in a broad way, simply as indications of the questions which have been large in the minds of various managers.

Water Rights.—The extent and limitation of water rights is a subject of never-ending discussion in many irrigated communities. Through the lapse of time, the more important of these questions gradually become settled, but in minor details they continue to arise. In order to discuss them intelligently, especially with men from the humid region, it is necessary to have clearly in mind that the conditions which have prevailed in the older states, notably those pertaining to riparian rights, do not exist in the arid West.

Most of the states of the Union, excepting those within the arid region, have adopted in one form or another the principles of English common law regarding waters, the effect of which is to safeguard to the owner of land through or along which a stream flows the continuation of this stream undiminished in quantity and unchanged in quality. This conception, which has gradually crystallized into law in most English-speaking countries, is opposed to the conservation and use of the waters of the arid region. If put into effect, it would prevent the irrigation of any considerable amount of land, as the watering of such land must necessarily result in diminishing the flow of some stream.

In a few of the Western states, particularly California, which has an arid and a humid portion originally settled by different types of people, there is more or less conflict of law and of court decision. For example, in the northern or humid parts of the state, there has been a tendency to adhere to the doctrine of riparian rights, while in the far southern, especially in the localities settled by Spanish-speaking people, the doctrine of appropriation and use of the water was early adopted. In other states, however, which are wholly within the arid region, the common practice confirmed by legislation has been for the first comer to appropriate and take for use on his land as much water as he needed; the next comer taking a portion of what was left, and so on, the first in time being first in right, and this right being limited by beneficial use on the land.

There is also a difference to be recognized in these rights. Uses of water for domestic and municipal supplies are superior to those for irrigation. In turn, irrigation is superior to manufacturing and development of power, so that in case of conflict there is usually first considered the needs for the support of human and animal life, next those for food supply and the growing of plants, and third, the industries.

The irrigation manager can hardly be expected to go into these matters in detail, but he should at least have clearly in mind a few of the fundamentals and be fairly well acquainted with the state laws and decisions concerning the water rights pertaining to his particular project.

Beneficial use.—The Reclamation Act of June 17, 1902, concisely states the maxim " that the right to the use of water acquired under the provisions of this act, shall be appurtenant to the land irrigated and beneficial use shall be the basis, the measure, and the limit of the right." In other words, although a man may have acquired an amount of water equal say to three acre-feet in depth on his land, yet if through any cause, such as seepage, his land does not require three acre-feet, he cannot sell or dispose of the excess, but must confine his demands to that amount of water which he can beneficially apply, any excess going back into the general stock to be utilized by those next in order of time.

At a conference in Salt Lake City, Utah, in November, 1913, a definition of beneficial use was attempted as follows:

A water user with a vested water right limited to beneficial use is entitled to that amount of water that will render him a reasonable maximum amount of good with a reasonably economic handling of the water. Since he has acquired his vested right from the laws of his State, he is entitled to protection of that right by the State; but it is his duty to the State, and the people of the State have the right to demand of him that he use every reasonable method to reduce the amount of water required to a minimum.

This demand requires the water user:

a. To make reasonable preparation of the ground surface for irrigation.

b. To use good judgment in selecting appropriate methods of applying the water to the ground.

c. To prepare reasonably efficient dikes, ditches and structures to get the water over the land in such a way as to reduce the underground losses to a minimum.

d. To irrigate the ground with such a head and at such intervals as to require a minimum use of water for proper irrigation.

e. To cultivate the irrigated ground when practicable to prevent undue losses from evaporation; in some cases possibly to govern the character of crops to be grown.

It is evident that the reasonable degree of perfection of each of these requirements will vary with the locality and with different changing conditions in each locality, so that the beneficial use of water is a variable.

Economical Use.—Since the water supply available for irrigation in the Western states is adequate for only a relatively small percentage of the entire irrigable acreage, the fundamental standard of economical use must be the financial results accomplished per acre-foot of water applied rather than the yield per acre irrigated. It, therefore, becomes necessary and desirable to impress irrigators with the fact that in general the largest net profits per acre-foot of water applied are obtained, not from using excessive quantities, but from more careful use of relatively small quantities.

In developing a more economical standard for the use of water, it should not be presumed that established rights can be limited to less water than they would carry under the accepted rule of beneficial use; yet by constantly bearing in mind that the ideal ultimately necessary must be the highest net profit per unit of water applied, irrigators may gradually be induced in many instances to obtain for themselves these results, and those undertaking the construction of new projects may be led so to design their systems as to provide a liberal water supply during the development period with a view to ultimate development based on economic use.

In the history of irrigation in this country, there has been evident a gradual but very definite evolution in the ideas of what constitutes proper use of water. While the use of water for irrigation was at first a relatively unimportant one, its importance now overshadows all other uses, save that of domestic supply.

In the course of this evolution, the doctrine of beneficial use has become established, but in future development this doctrine must in many cases merge into, or be supplanted by that of economic use.

"The doctrine of beneficial use looks to individual interest; that of economic use to the general welfare of society as a whole. So far as possible, water charges, systems of distribution, and regulations should be so adjusted as to make the interest of the individual water user coincide with this public interest."

Rights of Way.—The canal system and various structures occupy certain tracts or parcels of land, the title to which has presumably been obtained before the works are completed. The character of ownership or possession of each tract should be carefully scrutinized by the irrigation manager to ascertain whether the right of way involves the complete ownership of the land or is simply an easement for a particular purpose.

In the case of complete ownership of the lands acquired for right of way, vigilance must be exercised to see that encroachments are not made upon these lands. There is a tendency for individuals to erect small structures, bridges, water wheels, outbuildings, and various devices upon the right of way, and by sufferance obtain vested rights to the enjoyment of the use of the property. Sooner or later, there is necessity for changes or repairs to the canal, and these innumerable small structures become obstacles to the economic conduct of the work.

To guard against such contingencies, the character of the title to the right of way should be kept fully in mind, and the limits plainly marked with permanent stones or monuments, so that there can be little opportunity for controversy to arise regarding the exact position of the boundaries. Wherever possible, the right of way of the main canal and of its principal branches should be fenced to prevent encroachment of cattle and to establish beyond question the matter of proprietorship and control of the land.

Desert Land Act.—The legal basis for title to irrigated land in the arid region rests on a number of federal laws, the most important of which are the Desert Land Act, the Carey Act, and the Reclamation Act. In addition, large areas of land have been acquired by individuals under the terms of the Homestead Act and other acts, and by corporations under the grants made to transcontinental railroads or to states, of the swamped and overflowed lands donated to the latter for purposes of reclamation.

The Desert Land Act was the first distinct recognition by Congress of the need of irrigation in the development of the West. It provided in effect that any individual might select 640 acres, afterwards cut down to 320 acres, on condition of irrigating a portion of this land. The terms are very liberally interpreted and under them large areas of lands passed into the hands of individuals and corporations without the acutal reclamation and cultivation of any considerable portion. In fact, at the present time, the great bulk of the land taken up under the terms of the Desert Land Act still remains in its desert condition and is being held either for speculative purposes or forms the larger part of extensive grazing ranges of cattle and sheep companies.

It is unfortunately the case that the lands which have been granted to the states for reclamation, such as the swamped and overflowed lands, and those transferred to individuals under the Desert Land Act under conditions of irrigation, have both failed largely of that purpose, because of the lack of enforcement of the requirement of actual reclamation and the substitution therefor of so-called "constructive" reclamation in the sense that proof has been offered and accepted without actual verification of the facts.

The irrigation manager is concerned in this matter largely in knowing that certain lands whose title has been obtained through reclamation under the terms of the Desert Land Act, have not necessarily been reclaimed, and do not, therefore, always possess complete water right.

Carey Act.—Under the terms of the Carey Act of 1894, certain Western states were allowed to select upwards of a million acres, lately increased in some cases to two or three million, under condition that the state would arrange for their irrigation either directly by the use of state funds or by agreement with some corporation. The latter has been the invariable rule; the lands thus selected by the state have been the subject largely of speculation by investors more interested in the immediate profits of handling the lands than in the actual development of them.

The state officials are supposed to safeguard the interests of the future settlers and see to it that the works built are properly planned and completed; that there is an adequate water supply, and that the costs to the settlers for water are reasonable. As a matter of fact, the state officials charged with this duty are those who are already overloaded with other duties, who have no special knowledge or experience in this class of work, and who, through lack of continuity in office, cannot make use, for any considerable time, of the experience gained.

The results which have followed the attempts made under the Carey Act illustrate the fact that a difficult and complicated business of this kind cannot properly be intrusted to *ex officio* trustees or directors elected for political reasons and serving for short terms. It is as impossible to achieve good results in irrigation as it would be to operate a manufacturing establishment or a railroad line, under similar conditions of control.

The consequences have been as might be expected: many experiments have been made, large sums invested, some works completed, most of the projects in bankruptcy, with loss of credit for irrigation bonds or similar securities. In time, after reorganization and several new starts, some of the works have been put in fairly good shape. Meantime, many of the settlers have become disheartened, and the irrigation managers in charge of the works have had extreme difficulty in developing any consistent system of operation and maintenance under the changing administration or control of the work.

Legal questions which arise in this connection are of such far-reaching and difficult character that the best of legal talent is none too good. The irrigation manager must have access to competent and well-informed lawyers experienced not only in the state laws regarding irrigation and Carey Act projects, but also with the federal laws having to do with the acquisition of title under the conditions existing.

It is, of course, impossible for the irrigation manager to have more than a very general oversight in these matters, but he must be kept continually informed on the details and seek for guidance in order to keep as clear as possible of the almost innumerable complications which arise where financial troubles exist and where the settlers feel that they have not been fairly treated.

Reclamation Act.—Under the terms of the Reclamation Act of June 17, 1902, the United States has invested certain funds derived from the disposal of the public lands in the construction of irrigation works. The lands which at the time of the beginning of the works were in public ownership are disposed of under the terms of the Homestead Act to actual settlers and in small tracts. The Government, having ample funds for building the works, has constructed them with a degree of thoroughness and permanence not practicable for the corporate investor. It has thus set certain standards of construction which have been followed in part by later private builders. It has also given more attention to the question of providing an adequate water supply. Being relieved of all questions of profit and of interest returns on the project, it has been possible to build substantial works at less price to the water user than could be done by the private investor.

The irrigation managers under the Government works, utilizing the experience of older organizations, endeavor to put into effect systems of operation and maintenance based upon sound agricultural and business practices. In this respect, a standard has been set as in the case of construction of the works themselves. The legal questions which come to the cognizance of the manager are relatively simple as compared to those which may come up under the somewhat confused conditions on the larger private projects.

The federal law itself is quite explicit as regards the building and operation of the reclamation works. The acquisition of title by settlers under the terms of the Homestead Act has been the subject of many decisions, so that most of the questions which arise have been determined and definite information and advice can usually be had on these points. The manuals provided by the General Land Office and by the Reclamation Service enable the manager to secure a fairly good idea of these legal difficulties and while it is not expected that he will be immediately involved in them, he can at least obtain such broad knowledge as to be able to avoid some of the pitfalls which exist where the legal conditions are less well known and developed.

Cultivation Requirements.—The requirement of cultivation imposed by the Desert Land Act, the Carey Act and many similar laws, has been general in character, and has not always been enforced. Thus, relatively little of the land, the title to which has passed from the Government under conditions of cultivation, has actually been put to use in producing crops. The object of the men in obtaining lands under these laws has not always been to make a living or a profit out of the sale of products of the soil, but on the contrary to gain for themselves the unearned increment in value of the lands by subdividing and selling them in small tracts or of consolidating them in large holdings for future advance in prices.

This condition should be borne in mind in considering the general economic development of the country and in comparing statements of products from areas alleged to be reclaimed, but not actually tilled, with the average crop production on well-cultivated lands. It illustrates also the fact that in all questions of irrigation management, there must be had for guidance reliable statistics concerning degree of cultivation and its relation to the actual amount of crop produced in order to obtain intelligent views concerning the real benefit of irrigation.

Residence Requirements.—The requirements of residence, as in the case of those of cultivation, have as a rule been cut down to the very minimum, and even then have not been strictly observed. On some of the Carey Act projects the minimum term of residence has been as low as thirty days, so that it has been possible for a man living in town or in another state to take his summer vacation out on his " homestead " and acquire title by a few weeks camping on the selected spot. Under the terms of the Reclamation Act, however, actual, bona fide residence of three years is required, the theory being that the expenditure made by the Government in reclaiming these lands is justified only by the acquisition of a resident citizenship. If, as in the case of the Carey Act projects, men can come out from centers of population, spend a few weeks on the ground, then acquire title, go back to the cities, there results a sparsely settled area with a population composed mainly of tenants. The state is thus deprived of the increase in resident landowning citizenship, essential to its continued prosperity.

It is of no particular benefit to the community as a whole after the work has been built to have the lands held by non-resident owners and cultivated by tenant farmers. The soil is generally impoverished under the renting system. The local improvements such as roads, bridges and schools are neglected, the towns do not receive normal growth, and the great investment made in bringing water to the land is of relatively little use, as the irrigation system is not furnishing water to more than a small proportion of the land which it can supply.

On the other hand, it is urged that the requirement of actual residence on the ground is extremely onerous and that especially in the case of orchard development, years are required before the farm is put on a producing basis. Meantime, it is asserted, the owner should be permitted to live in town or in some other state and put a part of his earnings into the improvement of the farm.

This theory is excellent if it is based on the facts, but a relatively small percentage of non-resident owners do invest their earnings effectively in their farms. Far greater damage is being done to the lands by the careless handling of the soil and water by renters, so that at the end of a few years the owner seldom finds that he has a farm which is worthy of his personal attention at least to the extent of living upon it. When it is considered also that most of the young orchards never reach maturity and that, as stated by horticultural experts, probably not more than ten per cent. of the orchards which are set out on irrigated land have any commercial value, the fallacy of this theory becomes apparent.

The enforcement of the legal requirement of residence on the part of the manager involves, however, many questions, especially where the attempt is being made to put the newly irrigated land in fruit. Where a man and his family are actually living upon the land, as is evident to the neighbors and to the canal-riders who pass the place every day or two, there can be no question involved, but, as frequently happens, the owner after setting out some trees spends perhaps only a few weeks in the year actually on the place, but claims that his family or a portion of it are residing there or that he has made arrangements with a relative, then there are a number of very nice questions which naturally the manager desires to avoid entering into if possible. It is also questionable whether the manager should be held responsible for the enforcement of the residence requirement and thus be compelled to be both the prosecuting attorney, judge, and jury in matters of this kind. In fact, because of his numerous other duties, this matter of residence requirement, while kept clearly in mind by the manager, should be left to determination by some other authority.

Size of Farm Units.—The success of the farmer is dependent more largely upon the size of the farm which he attempts to cultivate under irrigation than upon almost any other single factor. As a rule, most men attempt to handle more land than they can properly cultivate. The man who has sufficient capital and experience to acquire and till 40 acres is apt to use his capital in making first payments on 80 acres and then diffuse his efforts over the whole tract to an extent such that the yield is less than it would have been had the owner confined his efforts to 40 acres.

The slow development of the irrigated regions is due largely to the fact that a great proportion of the irrigators are attempting to pay for water for 80 acres out of the products of from 20 to 30 acres which are actually well tilled. The men of average means and intelligence who are making a success are those who are confining their efforts to 40 acres or even less. While there are men who can handle even larger tracts, yet these men are exceptional and their example cannot be urged as typical.

The Desert Land Act set the limit originally at 640 acres to be acquired by one man, and later cut the area to 320 acres. At a still later date the fact became apparent that it was impossible for a man of ordinary means to properly irrigate this area or any considerable part of it. The Carey Act reduced the limit to 160 acres, and as the lawmakers began to appreciate the true conditions of irrigation, they finally in the Reclamation Act of 1902 placed a limit which "shall represent the acreage which in the opinion of the Secretary may be reasonably required for the support of a family upon the lands in question." The lower limit was originally 40 acres, later reduced to 10 acres, when it was appreciated that on some of the lands, especially in the southern arid regions where the irrigation season extended throughout the year, 10 acres are all that are needed, under good care, to support a family.

The enforcement of legal requirements regarding the size of farm units rarely comes to the attention of the manager, as after the irrigated land is once subdivided and settlement has progressed there is tendency to subdivide rather than to consolidate holdings.

Unlawful Diversion of Water.—One of the most vexatious problems encountered by irrigation managers is that growing out of what in plain language is the stealing of water, or to put it in another way, the irregular or unlawful diversion of water at times or in quantities not in accord with the proper system or to lands which

Immigrant Settlers "Ready to Make the Desert Blossom"

Settler's Home and Crop.
The sandy soil produces heavily when first irrigated.

are not entitled to it. There are innumerable legal questions which may be involved and some of these necessitate decisions on very fine points of law. Especially during the first few years after an irrigation system is completed and when there is usually more water provided than there is land ready for use, there are many attempts made by individuals to take more water than the amount to which they are entitled, or to evade payment for that which has been taken or used.

This stealing of water and evasion of regulations or payments is as old as agriculture itself. The earliest known code of laws found on fragments of ancient tablets attempted to deal with this matter. Human nature of to-day is practically the same as that of the time when men began to commit their ideas to writing. The watermasters and local magistrates then as now were confronted with the same kind of questions and had similar difficulties in adjusting conflicting claims.

As time goes on and each irrigation system comes into more complete use, local customs are established and there grows up a public opinion which recognizes the need of enforcement of rules and regulations, gradually supporting the manager in his efforts. But at all times this popular support drags behind the watermaster's standards or ideals. Thus being in advance of mature popular opinion, he is peculiarly exposed to attack from the rear as well as from the front. By showing clearly the evil effects to all the people which result from permitting any one man to take more than his share, he slowly convinces the majority that water which is flowing in the canals or which appears to be so plentiful, cannot be freely taken and put on the lands at any time or without suitable authority from the man charged with its distribution. The only way to do this is to have accurate records as indicated on page 104, showing the amount of water which is available for all the people and the effect of unlawful or irregular diversion of this in taking something from the common stock and in depriving others of their fair share. There is always apt to be more or less local politics mixed up in these matters, complicated sometimes by the ignorance of local magistrates or judges as to the law, and the necessity of its proper enforcement. Many times the careful work of the manager in detecting the theft of water at night has been defeated by the indifference of the public, but in the long run the efforts in this direction are ultimately appreciated.

CHAPTER V

OPERATION ORGANIZATION

THE distinctive features of operation have been previously described as consisting of those details which have to do mainly with conveying and distributing and measuring water to the various users. The organization needed for this purpose is quite different from that required in constructing an irrigation system. Its particular form as regards number and character of men employed, is dependent upon the size of the system, the number of acres served, and more particularly upon the number of different points of delivery, as well as upon the character of the crops and soil. There is a certain similarity between all operating organizations, whether for large or small canals, as all must have one responsible man in charge who subdivides all duties in accordance with the conditions just noted.

REQUIREMENTS.—Where the irrigable area consists of a large number of small fields with widely diversified crops and orchards, a relatively large number of men are required to operate the system, far more, for example, than in a case in Montana where on one of the older large canals there are only sixty points of delivery to supply over 12,000 acres, and where there is practically continuous flow to each of these points of delivery. It is possible in this latter case for one man employed as canal-rider to visit these sixty points with sufficient frequency to give the necessary attention. If, however, this area of 12,000 acres were divided into 20-acre farms, there would be possibly 600 points of delivery with frequent changes at each point, necessitating perhaps ten men busily employed in the place of only one partly occupied.

Operating Force.—The body of men commonly known as the operation and maintenance force consists of the irrigation manager and assistants, whose principal duty it is to operate the canal system, after the construction force have planned and built the work. The duties of operation are merged into those of maintenance, and frequently the same men who are operating the system devote a large part of the year, particularly the winter season, to the work of maintenance. There are included in the operating organization both field and clerical employees—the former consisting largely of engineers, some of whom have had experience in the construction of the work. All of these men must hold themselves in readiness to respond to a call for assistance at any hour of the day or night, for the purpose of repairing damage or to aid in protecting the works from injury by floods, fire, or any other cause.

Manager.—The principal man in direct charge of the operation and maintenance of an irrigation project is designated as the manager. He is selected primarily for business ability, tact and discretion in dealing with farmers and in handling the problems presented in a farming community. He may have acquired experience as an engineer or as a senior clerk who has had opportunity to demonstrate his ability in work of this character. Under him are usually two or more assistants, each having charge of separate canals or distinct portions of the project. For example, if the canals are taken out on opposite sides of the river, it is usually necessary to have an assistant on the north side and another on the south side. The manager employed on Government work usually holds an appointment in the classified civil service.

Superintendent.—The principal assistants of the manager of a large project are known as superintendents, or canal superintendents; each reports to the manager and has direct charge of a main-line canal and distributing system, or distinct unit of a large irrigation project. Under their direction are watermasters, canal-riders, gate-tenders, mechanics, and laborers. The superintendents are usually men who have had engineering or technical training, and who have been advanced for their demonstrated ability in handling men and materials.

Watermaster.—The watermaster is equivalent to the foreman of a small body of mechanics. He reports directly to the superintendent, or the manager where, as in small projects, there are no superintendents. The watermasters have direct oversight of the distribution of the water in certain large laterals and direct the movement of various canal-riders and gate-tenders.

Canal-rider.—The canal-riders are usually experienced irrigators, having the qualifications in education and general training equivalent to those of a skilled mechanic. These men traverse a certain prescribed line of canals and laterals, giving personal attention to the distribution of water to the farms, in accordance with a schedule determined in advance by the watermaster, under instructions from the superintendent or manager. The designation canal-rider is preferred to that of ditch-rider.

Patrolman.—On some of the projects patrolmen are employed on special occasions, especially with reference to guarding and patrolling points of danger on the main canal. As a rule they are not concerned with the distribution of water but more definitely with the protection of property, especially at times when the canal is running bank full. Frequently they are employed in the night-time, while the canal-riders perform similar service during the daytime.

Gate-tender.—Employees resident at or near certain important gates, such as those at the outlets of reservoirs or at the intake of main canals, are designated as gate-tenders. Their duty is to regulate the gates in accordance with instructions, usually by telephone. They are not supposed to ride or patrol any considerable extent of canal.

Inspector.—One or more inspectors reporting directly to the manager are usually required on large systems. They should have the qualifications and experience of a superintendent or watermaster, and should visit different parts of the system at regular intervals to check up the work of the canal-riders, note the amount of water being turned out of each opening, and investigate any complaints which may be made. Competent men may be detailed as inspectors from one project to another, or a watermaster or superintendent may be thus designated for temporary service.

Size of Operating Force.—The number of men employed is dependent, as before stated, not so much upon the area of the lands irrigated as upon the number of farms and of points of delivery. As a rule one canal-rider can look after from fifty to sixty points of delivery if the gates are not changed oftener than every other day; and can furnish a supply to 3,000 or 4,000 acres or more. Each group of eight or ten canal-riders and gate-tenders on any one large canal or branch of an irrigation system should be under the supervision of a foreman termed, as before stated, a watermaster or superintendent, the latter reporting in turn to the manager of the system.

If there are less than a dozen field men necessary for the operation of a canal system, there may be no necessity for superintendents, and the manager may be able to attend to all of the duties which in a larger system must be delegated in part to the superintendents and to watermasters. In southern Idaho it is stated that the number of watermasters and canal-riders in several of the systems is such that each canal-rider gives attention to approximately 2,500 acres. If every point of delivery is visited each day the number of canal-riders is materially increased, but in cases where the farms are from 80 acres to 160 acres, each, the number is reduced.

On the Sunnyside project in the state of Washington, supplying 3,000 farms, aggregating 60,000 acres, there are two superintendents, five assistants, or watermasters—most of them having engineering education—and five clerical employees, with nineteen canal-riders or patrolmen, making in all thirty-one men, or about one man for 2,000 acres, or one canal-rider for about 3,000 acres.

The size of the clerical force is dependent largely upon the detail with which the records are kept. As a rule it is wiser to have at first too many than too few records—cutting these down as experience shows that certain details are not needed. For convenience of comparison of size of force, canal systems may be classified as follows:

(*a*) Those supplying water for 2,500 or more irrigators and watering lands through several large canals, generally on opposite sides of the river, thus irrigating 100,000 acres or more: Here, there will usually be required a manager with at least two superintendents, each in charge of a large canal, and under each superintendent two or more watermasters having oversight of a large branch canal, and under each watermaster eight or ten or more canal-riders. Thus, this system will consist of fifty or more canal-riders and gate-tenders, half a dozen watermasters or foremen, two or more superintendents, and the manager at the head of all;

(*b*) Canal systems watering from 40,000 to 100,000 acres with one manager, two superintendents, and twenty or more canal-riders and gate-tenders;

(*c*) Smaller systems in which there is only a manager in direct charge of all of the work, supervising eight or ten canal-riders, and performing most of the field and clerical work himself.

There is always a considerable amount of business to be transacted in connection with any canal system, and enough men must be provided so that the manager may spend half or two-thirds of his time in the field and be relieved of most of the clerical work by a suitable office force. The superintendents in turn must also spend all of the daylight on the ground and not be burdened with office work to an extent that they must neglect the active field supervision. There is probably no greater mistake which can be made than in neglecting to have a thoroughly competent business man at the head of the organization; one who has had engineering training or experience and who can give his undivided time to the field work without being hampered by the endless routine of petty details.

Qualifications of Canal-Riders.—Each canal-rider should know the principles of measurement of flowing water, and have had some practical experience in obtaining the velocity by means of floats, measuring the cross-section, and computing the approximate volume. He should know the meaning of the words "acre-foot," "second-foot," and other terms. Most of the canal-riders ordinarily employed, picked up from among the local population, do not have this knowledge, and so far as practicable, they should be given a little elementary instruction, or be induced to take up a correspondence course, or better, attend a short winter course at an agricultural college.

In the use of weirs for measuring flowing waters the canal-riders should know something of the conditions affecting the weir, and appreciate the large changes in amount of the discharge of the water resulting from slight variations in the surrounding conditions. Continuous effort should be made by the manager to secure tactful, intelligent, and fairly well-educated men for these positions. More important than educational qualifications are the requirements that the canal-rider possess good sense, energy and experience in dealing with men. Most of the canal-riders on a project are obtained from residents in the locality, men who have a small farm, or are living with relatives. There are generally available in every irrigation community a few young men who have been brought up on the farm and who have had a good agricultural education. From among the canal-riders, especially, the young men of relatively good education and who have "made good," are usually selected the watermasters or superintendents. The efficiency or "team play" of the whole organization is increased by such judicious advancement to higher positions of canal-riders who have shown particular ability.

The canal-riders are in immediate personal touch with the irrigators, and it is important that they preserve a sympathetic attitude with reference to the difficulties of farming. This should not lead to favoritism or to any improper concessions. Firmness in adherence to regulations is essential, but at the same time this must be used with tact. The more skilled canal-riders should be employed throughout the year; it is not advisable to employ all of them; a certain proportion must necessarily be kept only during the irrigating season. Their time in the non-irrigating season can be effectively used as foremen of cleaning gangs or as master workmen; also in collecting crop statistics, compiling the results of the year's work, or in clerical lines, according to their ability and experience. A large amount of data must necessarily be collected and digested by well-informed men, especially with reference to seeped conditions, the rise of the water plane, and other matters which should be made available for study.

Duties of Canal-Riders.—The canal-riders, in addition to measuring water, are required to take proper care of all gates, weirs, measuring boxes, or flumes, and when these are out of repair promptly notify the watermaster or superintendent. They are required to exercise the greatest possible care in securing correct measurement of water, and to turn in the records promptly. No deliveries are to be made, nor changes in delivery, except upon written request from the water user. It may be required that this request be sent in twelve or twenty-four hours in advance.

The canal-rider should promptly warn all property holders against placing fences, bridges or other obstructions across the canal or main laterals, and see to it that before any encroachments are permitted upon the right of way suitable revocable licenses are given.

It is expected that the field men will use courtesyin their transactions with the farmers and be ready to consider any claim or grievance, being absolutely fair yet firm in the decision reached, trying to have a full understanding and appreciation of the honesty of purpose and equity of all acts necessary for the best possible service.

The canal management, as before stated, is in immediate touch with the irrigators through the canal-riders, gate-tenders and hydrographers. Too much emphasis can hardly be placed on the requirement that each of these men not only understands his business, but has a personality which inspires respect and confidence in his fairness and strength of character. These men should at all times be courteous in their dealings, even under great provocation, and not disputatious, nor given to argument, but willing to listen patiently to every grievance and make decision which, if not satisfactory, may be appealed without further argument to the superintendent or manager.

The greatest source of friction arises at these points of contact; and, as in any large machine, the bearings at these points must be carefully watched to see that there is no undue friction, tending to cause loss of energy, overheating, and consequent injury.

Each irrigator expects his share of water when his turn arrives, and to have this head maintained throughout the designated period of time. Unfortunately some of his neighbors are inclined to take more than their share, especially in times of scarcity, and the canal-riders must be eternally vigilant. There are also some water users, who are suspicious that the canal-rider is unfair to them or that some influence is working against their receiving their proper proportion. This is particularly the case where division is made by lateral organizations, and by some one man chosen from among the irrigators. It is very rare indeed that such a man can continue to divide the water for a season without quarrels arising and appeals made to have someone sent in from outside to make the division.

The canal-riders are expected to be ever alert n the interests of the water users, as well as of the public in general and see to it that no man suffers for lack of water through unfair action on the part of a neighbor, especially if the latter is a wealthy or influential member of the community or director of the organization. There is always a feeling that a large landowner or influential citizen is getting more than his share, and that the canal-rider may be improperly influenced and neglect the needs of the poorer members of the community.

It is recognized that in most controversies the competent canal-rider is more likely to be right than is the water user, because of his thorough familiarity with all details. Yet, any man is liable to make mistakes, especially if he is overworked during the critical times of the year. The water users, while properly asserting their right to have such mistakes checked up, must not expect infallibility.

Houses and Equipment.—At remote points where it is necessary to have a man living continuously to watch or guard a reservoir, or the head of a main-line canal, it is necessary to provide him with a suitable house and small area of agricultural land, where he can have a garden. These houses are built in accordance with the climatic conditions to accommodate a family and at a cost of approximately $1,000.

Canal-riders are largely employed from among resident farmers and usually live at home or with some relative. In some localities, however, it is not possible to find canal-riders, and here suitable houses may be furnished in order to enable them to live in the locality, a fair rental being charged, or deducted from the monthly pay.

The canal-rider is expected to furnish a motorcycle or one or more horses, and usually to supply the horses with forage. Sometimes he is equipped with a light two-wheeled cart, enabling him to carry a long-handled shovel, a few small tools with which to make repairs, and several sacks to be filled with earth and used in emergency to protect canal banks. On some of the projects motorcycles are used, as it has been found that a larger area can be covered by use of this machine than with a horse.

Telephone System.—The item of equipment most important in the operations of the canal-rider is a complete telephone system. Each project is usually provided with telephone facilities during construction to facilitate work, and the lines are extended to the home of each canal-rider, and especially to the gate-tenders, so that immediate action can be taken. It is essential that the telephone system be employed exclusively in the operation of the canal, and not used for other purposes.

MANAGER'S DUTIES.—The manager of a large irrigation system has duties which, in intricacy of detail are comparable to those of the manager of a railroad system. Under him are the superintendents or watermasters, canal-riders, and others as above described, having control of several hundred or thousand miles of waterways, in which a flow must be maintained from day to day proportional to the needs of hundreds or even thousands of farmers. It is by no means an easy problem, as changes in the quantity of water at the head of the canals are not immediately responsive at the lower points, and a day or more is required to bring about adjustment in water deliveries. Thus, following any radical change or rotation of water, two or three days may be required to bring about the desired effect, and this condition must be anticipated and provided for in arranging the distribution.

Comparing the operation of a canal system with that of a single-line railroad system, the canal manager has no sidings, and his traffic moves onward in one direction only; he must work out from experience a somewhat definite scheme of water deliveries and be prepared to modify this in detail from day to day, according to weather changes and the requests of the irrigators, complying with these where possible to do so without seriously interfering with the general scheme. His special care is for the irrigator at the far end of the canal or lateral, and if the last man can be satisfied, there is usually little trouble in serving the others.

In case of sudden rainstorms, prompt adjustment of gates and wasteways must be made to prevent flooding the canal and washing out portions of it. Most of the farmers desire to shut down their gates, and if this is permitted, the sudden closing of hundreds of these small gates may back up the water and wreck the canal unless ample wasteways have been provided and are ready for use. In many instances it is necessary to keep the farmer's gates locked, as well as all the larger gates, in order to prevent this interference with the proper flow of the water. The manager must avoid both of the two extremes:

First, that of endeavoring to conciliate, or gain personal popularity by giving to each water user all of the water which he demands, and thus saving himself from trouble; or,

Second, that of stiffly adhering to rules in such way as to appear unnecessarily arbitrary.

It is, of course, essential to be absolutely fair, and to adhere to the established regulations, and it is possible for a man of tact to do so without arousing antagonism.

The success of the project manager depends most largely upon his ability to understand and appreciate the needs of irrigation, and to handle those matters which lead to the success of the farmer, gaining his respect and confidence, and gradually building up, directly and indirectly, the returns of crops to the individual and to the community. The qualifications of tact, of sympathetic appreciation of the other man's viewpoint, and of absolute fairness and integrity, are of the highest importance; and, while it is necessary at the same time to have business ability, skill, some knowledge of engineering and other qualifications, no man can succeed as a manager who does not have as the leading qualification, the ability successfully to meet and deal with the average farmer on the project.

In arranging his affairs and daily routine, the project manager, as before stated, must provide for being on the ground, visiting different parts of the project, meeting the farmers in their fields, for one-half of his time.

During the remaining days he should be readily accessible in his office, and while guarding himself against undue loss of time and effort, yet he should create the impression that he is always ready to see the farmer who has come in from a distance. Experience has shown that it is possible to do this and rapidly to get at the matter in the mind of the farmer—using tact in so doing, and excusing himself for other business the moment that the essential has been reached. The tendency is, of course, for the average countryman to spend hours talking over some minor matter, and consume the entire time of the manager, but this condition, when recognized, must be carefully guarded against.

On all projects there are likely to prevail vague rumors of bad work and general complaints which tend to arouse animosity against the management. Efforts are frequently made to find the origin of these rumors, and to stop the wild talk, but it is usually difficult to trace back these statements to their source. In some cases committees of inquiry have been appointed or designated, but after fruitless effort they have usually become disgusted and stopped the inquiry.

The difficulty of obtaining and keeping good irrigation managers arises largely from the fact that there is not yet in the minds of the public an appreciation of the difficulties of the situation and of the requirement of men, not only with experience, but possessing a rare degree of tact and ability in dealing with the ordinary man. There is still a tendency to believe that any irrigator can operate an irrigation system. This condition is pointed out by the following statements from one of the men who has long been employed in irrigation works:

. . . The oldest and most-up-to-date ditch companies make the same mistake—that of employing superintendents, or ditch-riders, as they are more commonly called, that are thoroughly incompetent to have charge of an irrigation canal, with the result that through ignorance they make mistakes which cost the farmers hundreds of dollars in the loss of crops, and the company an unnecessary expense.

The farmers and water users will continue to pay unnecessary expenses as long as they hold to the idea that anyone can be a canal superintendent. In this company they had practiced hiring cheap inexperienced men until their canal and appurtenances were almost a total wreck. In 1908 a new board of directors were elected who realized the situation and accordingly took steps to improve it; they raised the superintendent's salary 50 per cent., and employed a competent man who is still with us. The canal is now in better condition than the average. . . .

Relations with Water Users.—In all business relations, it is essential for success to preserve mutual respect and confidence and bring about cordial relations; at the same time not violating for the sake of popularity, essential requirements of law or of good practice. Personal differences and misunderstandings are to any organization what friction is to a machine—consuming power, retarding motion, damaging and ultimately destroying the most costly device. It must be eliminated by careful study of the origin of the friction, and by applying proper lubricants to the point of contact. This does not imply weakness nor subservience to unreasonable demands. One of the best machine lubricants is graphite, in some respects a hard and unyielding substance, but at the same time one which prevents the bearing surfaces from cutting each other.

An unvarying courtesy, consideration for the views of others, reasonable optimism, and cheerful response reduce and overcome the heat which develops in business contact. At first, in any new and large machine there are necessary points of roughness, and it requires a certain length of time to get the machinery shaken down and all bearing surfaces smoothed. The fact that this is not accomplished immediately is not a valid criticism but especial attention should be applied to the places of friction where heating does occur and these kept bathed n the oil of human kindness and consideration.

CHAPTER VI

METHODS OF OPERATION

THERE is a well-recognized tendency towards standardization of the practices in the operation of the irrigation system, particularly those of considerable size. The practices formerly divergent, are being made to conform somewhat more closely to methods applicable to all canals and one which the experience of the engineer or manager in charge is finding to be desirable. One of the inciting causes, in addition to that of efficiency, is to enable comparison to be made from time to time of the results being obtained in various localities. The desirability of uniformity is becoming more and more apparent, particularly in methods of delivery.

DELIVERY OF WATER

There have been practiced many methods of delivery of water from the main canal to the irrigators and consumers. These are gradually being grouped under three general methods, as follows: (*a*) continuous flow, (*b*) delivery on demand, (*c*) rotation on schedule.

CONTINUOUS FLOW.—Most of the older and smaller irrigation systems were built on the theory of furnishing a continuous flow of water throughout the irrigating season, of say, one cubic foot per second to each farm of eighty acres. The small pioneer canals were built by individuals or associations of farmers who joined forces to build the principal canal and then gradually enlarged or extended the work, bringing water to each farm and dividing it pro rata. Water turned in at the head was allowed to flow down to the field and if not needed it was permitted to continue on through natural depressions back to the river. Whenever an irrigator desired to use the water he turned it to his land. As the demands increased it became necessary to apportion the flow, and finally some one man was designated to try to divide the supply equitably when it became scanty. There arose almost innumerable controversies over this division, especially when the larger farms were subdivided, and water more carefully used by a few of the farmers.

Delivery on Demand.—The owner of a 160-acre tract having a steady flow of 2 cubic feet per second for this area would naturally use this water first on one tract of 20 or 40 acres, then on another, turning the stream from one field to the next. When the time came to subdivide the land each owner of a 40-acre tract might elect to take his proportion of the continuous flow, or more likely would continue to practice a division of the entire flow, making a request upon his neighbors to permit him to have the full head of water during a short period of time, arranging for an exchange of time of flow. Thus, grew up naturally a crude system of delivery on call, often quite complex in its ramifications as different neighbors, or groups of neighbors, adjusted the needs of their crops to the continuous flow.

One man, for example, would arrange to take all of the water belonging to three or four of his neighbors for certain periods, and call for the united supply; then, later, his water would be combined in the general stock and made subject to call of the other neighbors as needed by them. This system worked quite satisfactorily for a time, when there were not many users, and is still followed where there is ample water supply, or where the canals and laterals are of sufficient size to permit a number of men to call for water at the same time without interference with each other.

Rotation.—In the event that the canal capacity is not adequate to permit everyone to obtain water at the same time, it follows that there must be some systematic scheme by which each may receive his share of the supply at periods to be worked out in advance, and according to some carefully considered schedule prepared with reference to the character of soil and crops. Taking, for instance, the case of an original owner who had 4 second-feet for 320 acres, this might be a convenient quantity to handle at one time as a single "irrigating head," and one which would be carried through the lateral canals. He may have been accustomed to using this in turn on each 40-acre tract. If later he subdivides and sells to 8 owners of 40 acres each, it is obvious that these 8 owners must agree among themselves as to when each may enjoy in turn the use of the full irrigating head. Thus, systematic rotation must be arranged according to some schedule, so that each irrigator may have either a full head of four second-feet for a certain number of hours, or half a head.

Where there are several hundred, or several thousand irrigators of small tracts, the preparation of a schedule to meet the convenience of these irrigators, and the needs of their crops, is a difficult and intricate matter, and one which to be successful must be the result of years of experience. A new, or unskilled manager, with the best of intentions, may interfere with the delicate adjustments which have taken place and bring about great confusion or loss through unwise attempts to improve the elaborate system which may have grown up.

Under some of the larger irrigation canals, even where a definite rotation system has not been established, it is customary for the water users to arrange among themselves to exchange water so as to increase the irrigating head locally available. This is notably the case where the farmers have discovered that the continuous delivery of a small amount of water is neither economical of their time nor of the water supply; they devise for themselves certain economies of time and water, and provide a system by which one man arranges with his neighbor to unite the water which would otherwise have been divided among two or more farms, using the larger volume of water, or head, for a few hours on one farm, then shutting it off completely and delivering to another.

Such an arrangement as above described may precede the adoption of a more complete system of rotation. It teaches the value of systematic rotation, and creates a desire for it, even though some of the farmers are not able, by their own efforts, to find neighbors who can, or will, exchange with them at the critical time. It is not always possible to rotate on the theoretically ideal basis, because the crops vary and the soils are not always of uniform texture; some dry out with rapidity, and require applications of water at short intervals. This is usually a temporary condition, and after humus has been supplied and the ground cultivated for some years, the irrigating head and the length of the rotation period can be gradually increased.

Various Forms of Rotation.—It is to be seen from the above statement that the phrase "rotation" covers a wide variety of practices in distributing water. It implies that, for any given tract of land, water is applied at intervals, and not in a continuous stream. In other words, it is in accordance with natural conditions where rains descend at intervals, wetting the soil, which on the cessation of the rains, becomes dry again, permitting aeration and cultivation.

As a matter of fact, no one piece of land which is not used for growing aquatic plants is given a continuous flow. Each small plot of land is alternately wet and then allowed to dry. If a landowner has a continuous flow at the edge of his 160-acre tract, he uses the water for a day or more upon his field of ten acres; then applies it to his orchard, and so on, rotating the delivery to the various fields. While many irrigators claim to have a continuous flow and successfully to irrigate with it, as a matter of fact they actually practice some form of rotation. Frequently they resent the introduction of a so-called "rotation plan," although they themselves are actually carrying it out under another name. The almost infinite variety of ways in which rotation may be carried on has arisen from the fact, as before noted, that most of these have grown up through informal arrangement among neighbors as above described by which a more or less elementary schedule is agreed upon—one man taking water on a certain day, and turning his share to his neighbor the next day, and so on.

A time may arise when the crop conditions are such that none of the farmers need to utilize the water during certain days, and they appreciate that the steady flow is tending to raise the ground water and swamp the lowlands. They therefore agree that the lateral shall be shut down for a period of several days and dried out or cleaned. The water which would otherwise have gone to this lateral can then be used on other lands, and the result is the practice of rotation between laterals as well as between fields.

With a more highly developed system of management, it is possible to make a schedule such that not only the small laterals, but larger branches of the canal may be shut down for a period of from four days to a week at a time, allowing larger areas of ground to dry out, be cultivated and aerated and brought into the best possible condition. Rotation between any considerable areas of land is, however, a matter requiring long experience and the careful working out of a schedule such that the farmers may make provision to plant and cultivate their crops with full reference to the rotation system. In the case of young alfalfa, or of gardens, it is not always possible to arrange complete rotation, but provision must be made for these, also for stock water in new countries where the farmers have not yet provided an adequate supply.

In practice, it is usually desirable to give to the man at the far end of the lateral a full head for a certain number of hours, then his gate is shut down and the next man above receives the full flow for his proportional number of hours and so on day and night. (See also p. 93.) Little question can arise as to fairness of division under this method, because each man has the full flow maintained at a steady rate for a definite time.

It is not always possible, however, to follow such a simple device, as with various crops on different-sized holdings it may be necessary to supply two or more small farms, say of ten acres each, at the same time—

so that the single measurement at the head of the lateral will not suffice. Thus, gradually, the division becomes more and more complicated, especially where water is rotated between separate laterals.

Rotation Period.—As far as practicable, it is desirable to have the individual farmer decide for himself the length of the rotation period, and the head of water with which he can attain the best results. This can usually be done within certain limits, where the farmer works with a coöperative spirit and is actuated by a desire to join with his neighbors in producing the best results for the community. It is necessary to have his personal interest in this matter in order to promote a high duty of water, make the canals easier to operate, reduce the seepage, and give better returns. In any community, unfortunately there are men who are unwilling to join with the rest in any desired reform. For example, in one instance a man has demanded an irrigation head of six second-feet of six-day rotation on a twenty-acre tract of sod, an amount sufficient to swamp the neighborhood, and yet this man is a prominent farmer and business man, skilled in other occupations, but wholly unreasonable in his demands for water.

On the North Platte project in Nebraska the period is four days flow and four days off, furnishing an irrigation head of two second-feet to each eighty-acre tract. The farmers who have 160 acres or more have a six-day flow and three days off, if desired. When this system was first announced and before water was used, there were many theoretical objections, but after a month's use there was practically no complaint.

It is customary for the water user himself to initiate the delivery by making a request for a certain amount of water at a certain time. This is done by filling in a slip or card which reads about as follows:

August 1, 1915.

Irrigation Manager:

I hereby request delivery of water at the rate of 2 second-feet for one day, beginning on August 3, at turnout No. 421 on Jackson lateral, to irrigate the following crops:

10 acres of alfalfa
2 acres of orchard
1 acre of garden

John Smith,
Water User.

In filling in this request, it is usually required that at least two days' advance notice be given. If a considerable amount of water is needed a similar form is used which may read as follows:

August 3, 1915.

Irrigation Manager:

Please make the following changes in the water for my land: Deliver 4 second-feet to turnout No. 271 on Willow lateral, beginning at 8 A.M., and continuing until 3 P.M.

Or, the request may take the form of:

Change to 6 second-feet from turnout No. 124 on Brown lateral, to turnout No. 41, on Green lateral. . . .

spaces being provided for filling in the request to change the delivery or to close the turnouts, thus facilitating easy yet definite action on the part of the individual water user.

These requests are compiled each day on suitable records arranged for the convenience of the canal-rider, and approved by the watermaster, or superintendent of that division. The slip or card above described may either be mailed to the office of the canal superintendent or manager, or left in a small box provided for the purpose at the headgate of the farmer's lateral. These notices are collected by the canal-riders on their rounds. In case telephone facilities are provided, the request may be transmitted by telephone, but in such cases it is usually required that the written card or request be sent in due course of time to the manager's office, to verify the fact that water has been requested. The following application form has been adopted for use in cases where there is unusual difficulty in delivery of water, or where exceptional care should be taken to insure careful planning of the rotation:

APPLICATION FOR DELIVERY OF WATER OUT OF ROTATION SCHEDULE

Name of applicant........................Unit............
Area under cultivation..................................
Date for which water is requested.........................
The head of water requested..............................
Length of run requested.................................
Crop for which water is wanted............Acres...........
Was water used during last regular rotation?................
If so, how many acres irrigated?..........................
How long was water used? ....
If not irrigated last rotation, why?........................
Number of times this crop has been irrigated...............
Remarks: Give reason for wanting water at this time.........
....
....

(Signed).....................

Water User.

(To be filled out by Superintendent)

Number of times water has been delivered to applicant, season of 1912..

Total acre-feet of water used to date........................

Have you inspected the condition of this crop?...............

Does it require delivery of water out of rotation?............

Do you recommend delivery of water as per this application?..

Remarks:..

(Signed).............................

Superintendent of Irrigation.

Action taken..

Project Manager.

The table on page 89 shows the results of operation under schedule on the Huntley project, Montana, and is given to show how the water users naturally fall into certain practices at the outset. It indicates that about one-fourth of the water users were then receiving water each day, and about one-fourth every other day, the remainder receiving it at longer intervals. As experience has been obtained, the length of interval has greatly increased, with corresponding reduction in expenditure of time and labor by the farmers and canal-riders.

The method of operating the laterals of an irrigation system is largely determined by the amount of water turned to each farmer or by the size of the heads used by the individual irrigators. If, for example, relatively small heads are used, then a larger number of irrigators can be kept busy with the water from a given lateral, and the farmer's gates are adjusted at less frequent intervals, but more time is required in irrigation. On the other hand, if the farmers have become accustomed to using large heads, then the length of time required by any one irrigator for getting the water over his

HUNTLEY PROJECT

Length of Irrigation Periods—1912

Length of Period, Days.	Number of Irrigations.	Per cent. of Total Number of Irrigations.
1	604	23
2	610	24
3	502	20
4	415	16
5	177	7
6	113	4
7	98	4
8	28	1
9	19	
10	8	
Over 10	13	
	2587	

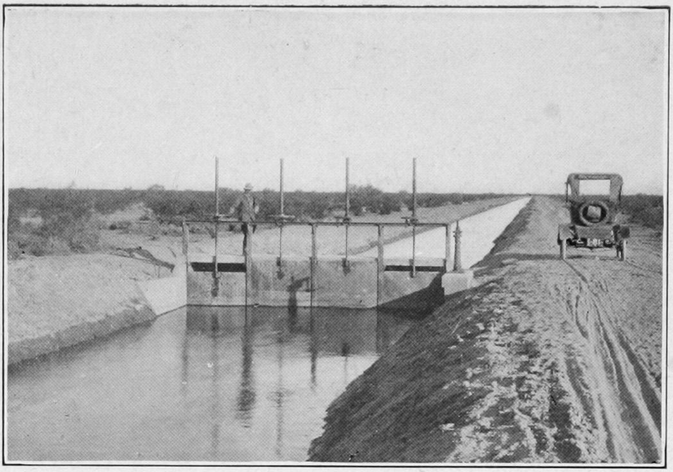
field is relatively short. The gates must be adjusted at frequent intervals and the schedule of deliveries arranged accordingly. The size of head found to be desirable under different conditions is further discussed on page 245.

PREPARATION OF FIELDS

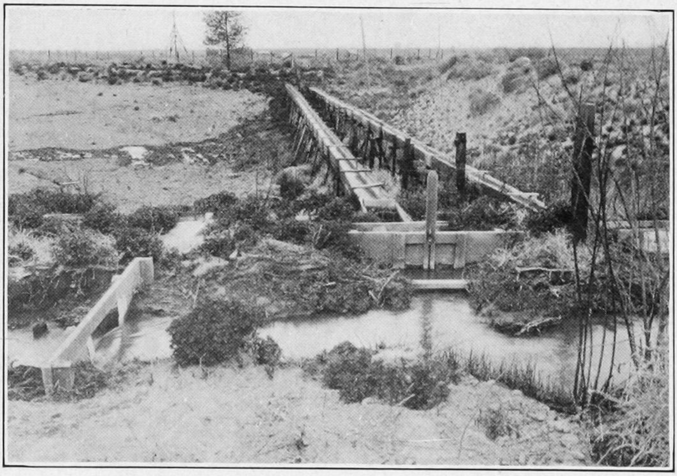
For economy of time and water, both in the operation of the system and in the processes of irrigation, the farmer's fields must be prepared to receive the water quickly. In other words, the surface of the cultivated lands must be made as smooth as possible, all depressions being filled and elevations moved, so that the water can be successfully conducted over the entire surface. If this is not done, low spots receive too much water, and the crops on them are drowned in the attempt to irrigate the higher points, unless the irrigator spends an extraordinary amount of time and labor in applying the water.

In the case of some fields in the arid region, nature has already leveled the surface, but in most localities it is necessary to incur large expense, not only in removing the native vegetation, but in smoothing down the ridges or hummocks, which have resulted from the growth of this vegetation, or from the wind action in piling up the sand around the scanty growth. Where the vegetation is particularly heavy, as, for example, on the alluvial or bottom lands, the cost of removing this vegetation is not only large, ten or fifteen dollars or more per acre, but the expense of leveling is often as much, or even more, because the ground has been furrowed or cut into gullies by the overflowing flood waters.

The cost of clearing and leveling some of the rich bottom-land soils may be as high as fifty dollars an acre, but the expense is justified. The quicker the fields are leveled the better will be the results in economy of time spent in irrigation and in water. It is not to be expected that the entire area of the farm will be brought into good condition the first year, but, as before stated, the irrigation manager should do everything possible to encourage the thorough leveling and preparation of at least a portion of the fields each year, this area being gradually extended as opportunity offers until the entire acreage has been brought up to the best condition for applying water. (See also p. 35.)



Concrete and Steel Gates in Earth Canal, Permitting Regulation of Water.



Farmer's Wooden Headgate.
Small flume and measuring weir at left.

FARM BOXES

Under the best conditions of irrigation development each separate farm or large field is provided with a box, or gate, for delivering water (see illustration), arranged in such a way that the flow can be controlled and measured. Under some of the older irrigation systems, especially where the farm areas were large, it was customary to deliver water in practically continuous flow, with few and simple gates, the water not being measured but simply divided by some rude device. The gates were set at the beginning of the irrigation season and were rarely changed until the time of summer drought. This resulted in great waste of water and in the encouragement of practices which cannot be tolerated under more highly developed systems where it is necessary to keep accurate record of the amount of water delivered to each consumer.

Many of the farm gates or turnouts placed during the earlier periods of construction were designed upon the assumption of delivering a relatively small continuous flow. Later, experience has shown that greater economy of water and of irrigators' time can be obtained by using larger heads of water for shorter periods. (See p. 248.) Thus it results that the irrigation manager in many instances must increase the size of the gates, rebuilding them with sufficient capacity to deliver to each farm the largest practicable amount of water consistent with the character of soil and crop. For example, the delivery boxes which were designed for a delivery of one cubic foot per second to eighty acres, flowing almost continuously, may be replaced to advantage by structures which can deliver as high as ten cubic feet per second, to be used during a period of a few hours. Frequent consideration should be given to this matter, with a view to insuring a still greater economy by increasing the size of the gates and farm laterals whenever opportunity offers.

Locking Boxes.—It has been found essential to make provisions for locking the farm gates in the same way that the gates to the larger laterals are kept locked. By so doing the canal-rider is sure that the gates are not tampered with, nor opened or closed to the detriment, not only of the irrigators themselves, but the liability of injury to the canal system. There are so many opportunities for mishaps to occur that, if the manager is to be held legally or morally responsible for the operation of the system, he cannot afford to take chances of some ignorant or mischievous person changing the water distribution in the absence of the canal-rider.

In old communities where the gates have not been locked, and where there has been a general indifference about water economy, or injury to property through flooding, there is usually resentment on the introduction of the more effective system; some of the farmers regard it as a personal affront when their gates are fastened. It should be generally understood that this is done for the security of all concerned, and is essential to the proper control of the system.

In promulgating rules governing the operation and maintenance of any canal system, it should be clearly shown that the manager has the duty of controlling at all times the headgates and other structures; and that he and his assistants have the exclusive right to the possession of the keys to all locks; and that no unauthorized person shall be permitted to tamper with the gates or change the locks.

METHODS OF OPERATION

OPERATING LATERALS

There are two well-defined systems of operating the laterals which take water from a main canal or its branches to the lands of a group of farmers. The first may be called the centralized system, and the second the community system.

Centralized Method.—Under the first system, or centralized method, the manager, or superintendent, of the canal is held responsible for delivery to the field of each individual farmer of a certain quantity of water; he has a definite schedule of water deliveries arranged in advance, and the necessary operating force to see to it that the water is distributed not only to the different laterals, but also from the lateral to each farmer.

Community System.—Under the second, or community system, the manager is concerned simply with the schedule for delivery of the water from the branch canal to each lateral, but not from the lateral. All of the individuals, usually a half-dozen or more, who receive water from each lateral, organize a community for the purpose of operating and maintaining the lateral and of dividing the water among themselves, the prime object being to reduce the cash outlay in cost of operation, by doing for themselves the work which would require the services of a professional canal-rider.

The lateral community, or group of water users, acting in a very informal manner, elects one of its members as secretary. He may, or may not, act as the watermaster. His business it is to keep record of the acts of the community and of the amount of water and time when it should be turned to the individual fields. There is also chosen from among the farmers a watermaster, if the secretary does not act as such, whose duty it is to attend to the distribution of water and to the cleaning of the lateral and the necessary repairs.

The community system, in theory, is nearly ideal, as it is the exemplification of home rule, or of local control, in which neighbors share the responsibility and divide the water among themselves, reducing the cost of cash outlay for clerical and other employees. It is in line with the immediate control of the canal by the people who are served by its waters; a condition which should be realized in all public utilities of this kind. Like most ideal systems, for success it requires ideal people. If each community has high conceptions of civic duties, and puts into practice the Golden Rule, success is assured; but if, as occasionally happens to be the case, there are one or two men who shirk their community duties, or who regard their own affairs as of superior importance to those of their neighbors, it invariably results that the weaker suffer. There is practically no appeal from the neglect of neighborly duties. If on a lateral supplying, say, twenty farms, a majority of the farmers, particularly those at the upper end, happen to be on unfriendly terms with the men at the lower end, they may not keep the ditch clean, nor let down enough water to the lower farmers, and the latter may be left without water, or may be flooded by the turning down of a large and unexpected quantity during the night, or when a rainstorm is approaching.

It frequently happens in new communities that there are small groups of men of different nationalities or religions, having little social intercourse with each other. Although they may intend to be fair in their distribution, there is always a difference of opinion as to what constitutes fairness. The man, or group of men in the minority, is apt to be oppressed to a point where he thinks that he must seek redress by force. It is extremely difficult and expensive to take such matters into court, as they are of the nature of neighborhood quarrels, and by the time the matter is settled the crops may be burned up for lack of water.

Thus it frequently happens that the apparent economies of operating under the communal system are more than overcome by the actual losses to individuals and by the destructive neighborhood quarrels which arise because of the lack of a simple, effective and quick-acting tribunal or official who can render immediate decision and rectify obvious wrongs.

It is for this reason that there is a tendency to turn from the community system to the centralized system, where all of the communities and people, or the entire project, are represented by a single man in authority, guided by law and by regulations laid down by all the persons concerned. He has the power to enforce these rules immediately, and to see to it that equity is done to each individual, no matter how powerless the latter might be against his unfriendly neighbors.

As an illustration of the practical working out of the community system may be given an instance from Idaho: The community officers there consist of a secretary and gate-tender, elected each year by the members of the community or district—each member casting as many votes as he has acres watered from the lateral. The secretary keeps the record of each settler's work in maintaining the lateral in repair. He also orders and superintends such work. The gate-tender receives from the canal system the amount of water required for the members of the district, and it is his duty to see to it that members in arrears do not obtain water.

The theory of this plan appears admirable. Unfortunately, however, it does not sufficiently take into account the vagaries of human nature. Usually the district officers are not paid for their services, and therefore do not care to exert themselves unduly in the performance of their duties. Often there are certain members of a district who insist in taking water to which they are not entitled either through not having paid the charges due or through being in arrears with their assessment work for maintaining the ditch. Unless the gate-tender is sufficiently courageous to be willing to provoke a quarrel with such neighbors by closing down their headgates and insisting on their share of work being performed or paid for, these men will take the water by force.

Several of the laterals being thus operated are from three to four miles in length and supply twenty to twenty-five farms. The farmers located close to the head of the lateral can obtain water with little work or effort, and hence they leave the men lower down to wrestle with the problem of securing water the best way they can. The former oftentimes hold back the water by checks in the lateral, so that those at the lower end can obtain but a very meager supply. There are usually no locks on the structures operated by a small community, and hence little check on individual action.

Thus, aside from the burden of maintaining long, sandy ditches, which are likely to blow full several times a year, the farmers on these long laterals have many contentions among themselves as to water service.

On some laterals, it frequently happens that some settlers for various reasons do not desire to use the water, and perhaps are absent from their ranches. This means that the balance of the members of that district are obliged to maintain the lateral at their own expense, as there is no way to collect from the men who will not assist with the work.

It is not to be supposed that the conditions outlined above exist on all canals. Many settlers acting under the community plan are receiving water from laterals which are comparatively short, and where each man is disposed to do his share for the common good, no trouble exists. On the other hand, even on a small district, the election of officers can be dictated by one or two farmers having the majority of acreage, and the ditch operated, therefore, according to their wills.

The burden imposed on the settlers by reason of the requirement to maintain and operate the laterals is an uneven one. Some laterals are long and sandy; others are short and give little trouble; while many settlers living adjacent to the main canals have their own private headgates, and, therefore, are at no expense for such lateral maintenance.

The system of individual delivery by a central authority is much more equitable; the cost is distributed evenly, and any complaint as to inability to receive water may be taken up directly with the general officers whose duty it is to remedy the trouble.

Community Canals.—A distinction is to be observed between the community distribution of water by small group of farmers under a large modern canal and that under the early pioneer enterprises built and owned by a small group of men related to each other or intimately bound by old neighborhood ties or united by interest.

These men have developed through years a certain practical scheme of coöperation which is enforced by a strong sense of mutual aid. In the case of a system built by outside capital, where settlers have come together from all parts of the world, the neighborhood spirit develops slowly, and a generation may have elapsed before this altruistic attitude is prominent. The newcomers do not get acquainted with each other readily, as each is busy getting started in his farm work, and during the first few years there is such shifting of population that few permanent ties of acquaintanceship can be established.

This condition is illustrated, for example, on one of the projects, where certain owners of lands agreed that the management should furnish water to the group, measuring it into the upper end of their lateral. This was done for two years, but the continual squabbles over the distribution resulted in urgent requests that the managers take over the operation of the lateral and deliver water to each individual. This was agreed to, providing the landowners would get together and put the lateral in good order, but even this simple detail was almost impracticable. The different owners had gotten into such a state of mind that they were not on speaking terms with each other and were utterly helpless to deliver water to themselves through their own lateral.

The experience of the Modesto Irrigation District in California is interesting in this connection, as the large private laterals built to open particular tracts of land, and originally managed independently of the district, have been taken over by the district at the request of the irrigators, as it was found that the water could be delivered more satisfactorily by the larger organization.

METHODS OF OPERATION

MEASURING DEVICES

Under ideal conditions, there should be a simple and accurate measuring device at the field of every farmer, by which the quantity of water delivered to him may be ascertained by the canal-rider and by the farmer himself. In this respect the situation of the individual farmer is like that of the water consumer of the city, where economy is promoted by the use of water meters for each house or apartment.

The ideal measuring device for irrigation is yet to be invented. There are almost innumerable methods in use, none wholly satisfactory, but some better adapted for one locality than another. The conditions to be met by a practical measuring device is one which is relatively inexpensive, strong, and "fool-proof"; does not obstruct the flow of water, nor require for its operation an excessive amount of fall of the water; and which is not easily clogged by weeds or trash but, at the same time, affords fair accuracy in measurement. The simplest and most generally used device for estimating the quantity of water delivered to the farmer is a rectangular flume or box, with a simple wooden slide-gate controlling the amount of water which can enter the box. This is located in the bank of the canal or lateral at sufficient elevation to receive water when the lateral is only partly full. It is placed at right angles to the bank, and nearly horizontal, or with slight fall away from the canal.

By adjusting the gate at the upper end, water flows through this short piece of flume, or box; the quantity of water is estimated roughly from the height at which it stands in the box—that is to say, if the box is 2 feet wide and the water is flowing with a depth of 9 inches, the area of cross-section will be $1\frac{1}{2}$ square feet; if the velocity of water in the box averages 4 linear feet per second, there will be a delivery of 6 cubic feet per second to the land. The width and depth of water can be easily ascertained but the average velocity not only varies from time to time, due to various causes, but is quite difficult to estimate with any degree of accuracy. This estimation is generally made either by a small current meter or by floats; or by chips thrown on the surface, giving an approximate result. As a rule, the practical irrigator trusts to his eye or general judgment as to the quantity of water which is issuing from one of these boxes.

The estimates made from these crude measuring boxes are sometimes quite close; in others, they may be 50 per cent. or more away from the truth. There is a tendency to underestimate, and especially if the water is moving quietly to assume that there is, for example, five second-feet, when measurement may show more nearly eight. Large quantities of water thus disappear mysteriously from an irrigation system, due to this reliance upon crude devices and to the assumption by so-called practical men that they can accurately judge quantities by the eye.

Wherever there is ample fall from the distributing lateral to the fields or the farm, the measuring device giving the most accurate results is the knife-edge weir. This may be either rectangular in shape or with inclined sides, as the Cippoletti weir, or the V-notch.

Weir tables, based upon experimental data, have been constructed for various sizes and shapes of meters and give results accurately within two or three per cent. To obtain this accuracy, however, it is necessary that the conditions surrounding the weir be kept similar to those of the experimental weir from which the tables were computed; the approach to the weir must be kept clear and a clear overflow be provided, without obstruction to the water in flowing away from the weir.

Where the available fall is slight, submerged weirs or submerged orifices are sometimes used. All of these devices require skill and attention, and for accuracy of measurement they should be systematically inspected by an experienced hydrographer who is capable of making accurate tests and determining the habitual errors. The canal-riders must, of course, make the daily rounds and record the height of water, and the hydrographer, visiting the same locality at longer intervals, should check up the observations made by the canal-rider and verify the assumptions as to quantities derived from these observations.

Use Book.—The details of methods of operation on each large irrigation project should be embodied in a small handbook or "Use Book" prepared for convenience of reference by the canal-riders, and containing instructions which are to be observed in controlling the water, and in the various relations with the water users. This should be accompanied by simple hydraulic tables and illustrations of methods of estimating the flow of water in weirs or boxes of various sizes.

In some instances a manual of the kind may be divided into two parts, one for the guidance of the water-masters, canal-riders and other employees, and the other part for the information of the water users. This latter should give in a form as concisely as possible the conditions which should be observed by each water user, for the general protection and for the welfare of the entire system.

CHAPTER VII

RECORDS AND SCHEDULES

In these days when "efficiency" is the watchword and when "costkeeping," "motion studies," "standards," "systems," and "dispatch" fill the columns of the engineering magazines and are creeping into current literature, the irrigation manager is being drawn into the general current and is inquiring into the modern up-to-date methods of keeping and analyzing the reports of his subordinates.

NEED OF SYSTEM

There is danger here of going from one extreme to another. Up to the present time the irrigation management has been conspicuously a rule of thumb operation, or rather a development by each individual in responsible charge of methods to suit his personal ideas. There has been no system or standard for comparison and the statements of cost of one feature or another are rarely comparable because they are not based on grounds of similarity.

The Reclamation Service of the Government with its twenty-five projects has found it necessary to adopt a certain degree of uniformity. Naturally the managers of private works, large and small, turn to it for suggestions in these matters. As a result, there has been brought together and published what is known as the

" Use Book " devoted to the details of operation and maintenance, and which gives forms for keeping records, these being presented for convenience of reference and with the idea of gradually bringing about a degree of uniformity such that comparisons may later be made as to the cost of all similar operations.

CHARACTER OF RECORDS

The proper maintenance of any irrigation works requires the keeping of some records; to facilitate the preparation of these, it is important to have blanks or forms which will give the information needed for immediate use and for future study. These blanks should be of such size and form as to be most convenient for use, and give the necessary facts in the most concise manner.

The most important records of any irrigation system are those based primarily upon the application for water by the consumers or water users, and the subsequent acts, those, in order of use, being as follows:

1. The application by the water user to have a certain quantity of water turned on or off at a designated time.
2. Schedule showing these requested or proposed water deliveries.
3. The record of the fact that certain quantities of water were delivered at definite times to described areas or crops.
4. The assembling of the total of water deliveries in comparison with the amount of water available or received into and delivered out of various parts of the irrigation systems.

These records of quantities of water and times of receipt and delivery are in many respects similar to the inventories of goods received and delivered by a warehouse. They are necessarily accompanied by the financial records showing the amounts of money due or paid, corresponding to the quantities of water delivered. While many irrigation companies keep fairly accurate books showing their financial condition, relatively few of them have developed a complete system of invoices or inventories of water such as has been found necessary in handling commodities in any well-conducted mercantile institution.

It is desirable to point out the analogy between the control of water as a commodity and that of the ordinary articles of commerce. It is easy to imagine, for example, that under crude conditions a merchant dealing for instance in coal could carry in his head the few facts of purchase and sale of coal to a limited number of customers or could divide up a given pile of coal by the eye among two or three or half a dozen purchasers. As his business increased and he was called upon to make deliveries to hundreds or even thousands of individuals, the old easy-going system would no longer suffice. He must develop more accurate methods of measurement and of records of time and quantities, such as were not necessary in the early days.

The same conditions hold true of the delivery of water. Under pioneer conditions where a few neighbors constructed a small canal, the distribution of the water was left to any one of the persons concerned; there was no particular necessity of keeping accurate records, as the transactions were matters of common knowledge. Thus, there has grown up a certain " free and easy " system of handling water in some parts of the West with the inevitable result that when it could no longer be a matter of common knowledge as to the respective rights of all, then there arose innumerable controversies and the condition sometimes described as "winter friendship" in distinction to the summer quarrels when, during the crop season every man was in controversy with his neighbor over the distribution of the water supply.

In the larger system controlled by corporations or by the Government, it is plainly evident that to avoid these endless controversies there must be instituted a well-considered system based upon good business practice and necessitating the keeping of simple but accurate records.

Application for Water.—The water user must judge for himself, as far as possible, as to the time and quantity of water needed for his crops and should make request in advance for an adequate amount. The compliance with this request, however, must be governed to a certain extent by the general conditions on the entire irrigation system, that is to say, each water user must conform to the limitation of the quantity of water available and to the capacity of the system for distributing the water. He cannot expect these requests for water to be acceded to if the aggregate of all requests totals up to a volume in excess of the capacity of the lateral or if his request is made for a date of delivery when, under a well-considered system, the lateral is not to carry water on that day.

It may require some years of experience before the individual water users can work together harmoniously in this respect and so plan the crops and till the ground that the needs for water and requests for it can be synchronized without more or less arbitrary action on the part of the watermaster. Many of the complaints on a new irrigation project arise from the fact that during the first few years there are apt to arise frequent misunderstandings on this matter. The adjustments which must be made by the men in the control of the distribution are apt to be regarded as unnecessarily severe. Assuming, however, that with the lapse of time the people as a whole become accustomed to the necessary restrictions, then each water user will ask for delivery of water within such times and in such quantities as may be consistent with the most economical handling of the water.

Requests for delivery are usually made by filling out some form of card provided for the purpose as shown on pages 86 or 107, or by a note written by the water user, giving the essential facts as to time and quantity. This card or note is usually left in a small box or tin can attached to the headgate of the farmer's delivery lateral, this receptacle being arranged in such a way as to protect the card from wind and weather, and to be readily accessible to the canal-rider on his daily rounds. If there is available telephone connection, the requests for water are frequently transmitted by telephone to the nearest watermaster and suitable orders issued by him. In every case, however, of telephone request, there should be a requirement that the request be followed by a postcard or other written form confirming the fact. In the case of disputes little weight can be attached to any oral statement which is not supported by such written evidence. It has been found in practical experience that unless this requirement is adhered to, there arise innumerable claims that water was ordered by telephone and that proper attention was not given to the order. Where the order is followed up by written communication, this fact can be proved or disproved.

WATER REQUEST

........................191...

I hereby request delivery of water at the rate of............

second-feet / miner's inches * for........ days / hours * beginning..........191...,

at turnout No..........on............lateral or canal to irrigate the following crops:..........acres of............; acres of.............; acres of...........................

....

....

....

Water User's Farm Unit or Holding	
........Sec....T....R....	
........Sec....T....R....	.... Water User.
........Sec....T....R....	
........Sec....T....R....	
(To be filled out by Water User)	

To the Water User.—In requesting water service give at least two days' advance notice of your needs, using one of these cards for each run of water from each turnout.

* Cross out word that does not apply.

Daily Schedules.—From the written requests made by the water users, there is made up a general schedule of distribution of water for the succeeding day. In order to prepare this satisfactorily all requests for water should be in the hands of the watermaster at least twenty-four hours in advance of the proposed delivery. Knowing the demands made upon each lateral it then becomes the duty of the watermaster to study these demands, to apportion the water from the principal canal to the laterals and from the laterals to the farm in such way as to accommodate the most farmers and at the same time operate the laterals efficiently.

It is desirable as a rule to arrange for water deliveries at the far end of each lateral as noted on page 84; that is to say, to consider first the needs of the man farthest away from the supply canal. If this is done, and the full stream is allowed to flow down to the end of the lateral, there is reasonable assurance that everyone will be able to obtain a proper amount. If, however, the man nearest the source of supply is first provided for, there is always danger that by the time the diminished stream reaches the lower end there will not be enough for equitable distribution.

The arrangement of the daily schedule, therefore, usually begins with provision for the lowest user and then with apportionment of quantity of water into one or more heads, arranging this in order upstream, so that the canal-rider can make continued progress and not be compelled to turn back on his daily rounds.

If all of the farms are of nearly equal size and the crop conditions are similar, the problem of distribution is quite simple; that is to say, if the irrigating head is three second-feet and each man in turn takes this full head for a certain number of hours, the schedule consists simply of noting the fact of turning the full capacity of the lateral to the lowest man a given number of hours, then cutting it off, and giving it to the next higher man for an additional number of hours, and so on, each receiving a supply on a time basis. The measurements under these conditions are simple as it is necessary merely to make a single measurement of the quantity flowing into the lateral and apportion this by hours and minutes.

Where, however, the capacity of the lateral is say fifteen second-feet, and the average use by each man is only three second-feet, then five water users theoretically may be supplied at the same time. Such division, however, necessitates measurement to each man and the complication further increases if the size of head going to each man differs widely; one person, for example, desiring less than a second-foot for orchard or garden use, another ten second-feet and so on. Under these conditions the work of the canal-rider and consequently his records become quite complicated.

In arranging the daily schedule, consideration must be given not only to all of these complicated matters, but also to the fact that the water is not flowing in a close or tight conduit and that there is considerable loss in transit, especially at certain points through seepage in sand or gravel. Thus allowance must be made for these losses and also for the length of time required for the water to traverse the distance of five or ten miles from the point of inflow from the supply canal.

The constantly fluctuating quantity in the lateral, due to the frequent changes of the gates or orifices leading to the various farms, renders the situation in practice quite difficult, and requires not only experience in that particular locality, but a degree of judgment on the part of the canal-rider which can be obtained only through months or years of practical operation.

Canal-Riders' Records. The canal-rider must be provided with a small notebook or card, of convenient size and arrangement for making note of the amount of water entering each gate and for recording all other matters of interest, as he is making his daily rounds. It is of the highest importance that this original record on the form given on page 111 be made on the spot and be preserved for future reference. There is constant temptation on the part of the canal-rider to neglect to make notes at the time but to wait until a convenient moment or until the end of the day and to trust to his memory regarding details.

The excuses offered for not making immediate entry are that the wind was blowing or there were other confusing circumstances or his hands were cramped or soiled by using a shovel or other implement, or he was fearful of not being able to make neat figures or write legibly while standing. He may be thus tempted to make certain rough marks on the back of an old envelope or scrap of paper and then transfer these to his notebook in the evening when he can sit at a table or desk and thus prepare a more creditable-appearing record. This, however, is the very thing to be avoided.

It is far better to have a rough and soiled original memorandum, which has been prepared on the spot and concerning which there can be no question as to the faithful recording of the facts as observed. Such notes made at the time may be amplified later, if necessary, but they should be preserved and filed for consultation in case of any question arising concerning the facts as they existed. If it is inconvenient to transmit the original notes to the central office at the end of the day, the transcript may be made and the original allowed to remain in the possession of the canal-rider until the end of the week or month, but ultimately they should be put upon the file in such form that they can be referred to readily.

Division........................

District........................

Date...................191.....

DAILY WATER REPORT

....
Canal-rider or Gate-tender

Water User or Canal or Lateral Served.	Turn-out No.	Canal or Lateral Drawn from.	Measuring Device.		Gauge.		Head in Feet.	Time Turned.		Hours Run.	Water Delivered.		Acres Irrigated to Date.*
			Kind.	Size.	Upper.	Lower.		On.	Off.		Dis-charge in Sec.-ft.	Quantity in Acre-ft.	
								M	M				
								M	M				
								M	M				
								M	M				
								M	M				
								M	M				
								M	M				
								M	M				
								M	M				
								M	M				
								M	M				
								M	M				
								M	M				

* To Canal Rider.—Unless otherwise directed by Project Manager, fill in this column only on reports for last day of each month, listing on such reports all the water users on your beat whether they receive water on that day or not.

Office Compilation.—The records turned in daily or at short intervals by the canal-riders form the basis of the more important office records relating to water delivery or losses, crop conditions, and other facts having to do with the economic administration of the system. As before stated, the original notes made at the time of observation should ultimately be deposited in the central office and so classified and arranged as to be accessible for ready reference in case of dispute. The fact that these original notes are thus available goes a long way toward preventing contentions from arising. Appeal to these has often saved a large expense in time and money in settling points which otherwise might have been disputed.

The essential facts given in the canal-riders' notes should be at once tabulated upon blanks, usually arranged in the form of loose-leaf ledgers, showing from day to day the total amount of water received and delivered at various points. The summation of these figures give not only the total use but also the losses which occur at various points. These losses should be carefully studied so that if the quantity appears to be abnormal prompt investigation should be made and the difficulties corrected.

The notes also which relate to crop conditions should be promptly assembled in convenient form for ready reference, so as to exhibit the acreage of various crops and the amount of water used or needed, thus permitting a broad consideration of probable demands for future deliveries. By having reasonably accurate data of the crop, acreage, and conditions, it is possible to arrive at the probable amount of water needed from any given reservoir or other source of supply, and to make corresponding arrangements for holding storage in reserve.

Checking Records.—From time to time careful inspection should be made to see that the records kept by the various canal-riders are reasonably accurate. This inspectiion should be done by the watermaster or superintendent or by an assistant to the manager. These men should visit various portions of the system at irregular intervals and go over the work of the canal-riders either with them or following them in such way as to ascertain whether the work is being carried on according to instructions. The inspector should also note the general condition of the crops and from conversation with the farmers ascertain the degree of satisfaction with the water service, in this respect supplementing the knowledge of the irrigation manager regarding these details.

Hydrographers.—All measurements and computations of flow of water through measuring boxes or other devices should be checked by competent engineering assistants from time to time to ascertain whether there are any notable errors in measurement. It frequently happens that weirs or other forms of measurement become obstructed by sand or by the growth of weeds. Thus the daily readings by the canal-riders may not accurately give the facts. It should be the duty of some one or more of the employees having engineering experience to systematically check these measurements. This work may be done by one of the superintendents or assistants to the manager, or in some cases by a canal-rider, particularly if these positions have been filled by young graduates from agricultural colleges who have had some engineering training.

It is highly desirable to let it be understood that the more intelligent or better-educated canal-riders may thus be advanced and designated as hydrographers after they have served an apprenticeship in the distribution of water. By so doing, encouragement is given to the men in the field to perfect themselves along these technical lines and an inducement is held out for more effective services.

Notices to Farmers.—Each farmer should be notified at short intervals as to the amount of water which he has received. Even though there is plenty of water for all, it is important to keep the farmer informed as to the amount delivered to him, as indicated by the form on page 115, so that he may guide his operations accordingly, and, if he is applying too much, let him know that improper use is likely to be of injury not only to his own land, but to that of his neighbors.

The making of necessary measurements and clerical work in notifying the farmers involves some considerable expenditure, but it is believed that this expenditure is well worth the cost, even on projects where there is an abundant supply of water. At first the farmers are usually incredulous as to the amount of water they have had, and even resent the statements sent to them, but in the course of time they come to look for these records as essential to their guidance. See also page 251.

WATERMASTER'S RECORD.—The watermaster or superintendent in charge of the main canal or of a large unit of an irrigation system should have desk room or space at his house or in a conveniently located office where a few necessary records can be kept and where daily scrutiny and compilations of the canal-riders' notes can be made. It is necessary to have telephone facilities such that the watermaster when at his desk during a certain small portion of each day will be able to keep in touch with the canal-riders and with such farmers as have telephone communication. All important events should be noted in his diary, and brief minutes made on what may be called his office blotter, of the requests for water, complaints, weather changes, and other items.

MONTHLY WATER STATEMENT

......................191...

Dear Sir:

Below is an abstract of water deliveries for this irrigation season to..............................at turnout....... on...................lateral(s). Any error in this statement should be promptly reported.

	Acre-feet of Water	
	Total	Per acre irrigated
Entitled to		
Delivered: Previous to		
During		
Total to		
Balance due		

Farm unit or holding.........; acres irrigable ....
Sec.....T....R....; ....Sec.....T....R....
.... Sec.....T....R....; ....Sec.....T....R....

Very truly yours,

....

Project Manager.

Inspection Reports.—Systematic inspection is necessary to maintain and improve the efficiency and economy of operation and should be carried on by the project manager, or by his assistants, acting as inspectors. The records of such inspection should be carefully preserved and arranged in such way as to show the true condition of the work performed by each man in responsible charge. The person acting as inspector should be free to visit any part of the work and should make note on the ground of the conditions of the work and of all matters which need attention. Included in this should be substance of conversation with water users and brief note of complaints made by them. It is only by systematic inspection and by preserving in concise form the essential records that any organization can be kept on a high plane of efficiency. The inspector's notes should refer to the water deliveries, amount of water found at various points at the time of his visit, and the condition of the structures, especially the gates, delivery boxes, and measuring devices, waste of water or seepage, development of alkali, necessity of cleaning or extending the drains, also the character of the crops, and the general attitude of the irrigators as indicated by conversation had with them.

General Records.—In the above discussion reference has been made mainly to those records which have to do with the delivery of water and keeping account of it as would be done in the case of any commercial commodity. Emphasis has been placed upon this matter because most of the irrigation systems, even those of considerable size, keep few, if any, records of this kind and to this extent, at least, the methods which are above described are novel.

In addition there are, however, other general records which, of course, must be kept, similar to those of any business undertaking—notably those which have to do with the collection of annual dues for operation and maintenance and installments on the cost of the water.

Also data should be preserved concerning the weather conditions, the status of the lands, the yield and condition of the crops, and at the end of the year a summary of what has been accomplished by the farmers as well as the totals of water deliveries, storage, losses, etc. All of these belong in the more or less ordinary methods of bookkeeping and of taking account of stock, but as before stated, the novel feature and one which should be more generally introduced is that of keeping careful record of the use and losses of the water in the irrigation system day by day throughout the season in which the canals are operated.

CHAPTER VIII

WATER ECONOMY

More Land than Water.—There is far more tillable land than there is water for the crops which might be grown upon this land. Such is the condition in the arid regions, which in area are estimated to form two-fifths of the entire extent of the United States. Here are millions of acres of good land, which can be cultivated whenever an adequate supply of water for irrigation is had. The quantity of this water, however, is relatively small and the extent to which this otherwise valuable land can be used for providing opportunities for homes for citizens is dependent upon the care with which the fluctuating water supply is stored and used on the lands. Every acre-foot of water saved may mean a half-acre of good land added to the productive capacity of the community. Economy in the use of water is thus not only a matter of personal profit but is a public duty.

To bring about the prevention of waste of water and the consequent reduction of the losses to individuals and communities, there must be a lively realization of the evil effects of this waste and a determination on the part of everyone concerned to bring about needed economies. No laws or regulations can be fully effective in this matter unless there is a deep-seated and united public spirit pervading the community, sustaining and urging forward the efforts of the responsible public servants, so that they will seek out each lapse and correct all negligence.

PREVENTION OF LOSSES

The avoidable waste of water in irrigation occurs in two distinct ways: *first,* losses in the open canals and laterals, taking water to the agricultural lands; *second,* and even more important, the excessive application of the water to the fields by the individual water user.

The prevention of waste from the canals is largely a matter for the engineer in charge of the work to carefully study. It is to a certain extent under his control, limited mainly by the financial resources available for lining the canals. The other, and usually more destructive wastes, which arise from the individual carelessness or lack of effort on the part of the hundreds or thousands of water users, are less susceptible of direct control. Lapses here must be met, as above stated, largely by the growth of a sound public sentiment on the part of the community.

Canal Losses.—The waste of water which occurs in transmission in open, earthen channels is greatest usually at the time following that when the canal system is first built, but as a rule it gradually decreases as the soil becomes more compact, and the pervious gravel bottom and sides of the canal are covered by a layer of fine mud, or sediment which is carried by the percolating water into the interstices between the sand or pebbles, gradually sealing these up.

Some main-line canals have been built through beds of coarse gravel or cobblestone, in which at first the entire flow disappeared in the course of its passage over a few miles. The finer material washed along by the waters, however, has gradually formed a lining. This process is assisted by putting a layer of clay or puddle in the bed of the canal or by turning in muddy water. In the course of two or three years, it results that with proper methods even these canals n gravel become reasonably tight and the water losses are gradually reduced.

The same condition prevails in the distributing or lateral system built through the ordinary surface soil. At first the loss of water is larger, but with careful manipulation and puddling the losses are reduced until the amount of waste through seepage is brought to a minimum of one per cent. per mile or even less.

Even with the best of care, it may not be practicable to reduce seepage losses in certain soils and there it becomes necessary to consider the question of lining the canal with cement or using a pipe to carry the water over the pervious area.

As a temporary expedient, on new canals wooden flumes are occasionally employed, but these quickly decay; if adequate capital is available they should be replaced by permanent metal or concrete-lined canals. The economy of water and ability to distribute it to other areas will usually justify the added expense, especially when the injury frequently caused by the water thus lost is considered.

The losses from canals and laterals are usually in proportion to the wetted area, that is to say, to the number of square feet or square yards covered by the water in the canal. It is dependent upon the character of the ground through which the canal is built. If constructed in rock, there is usually little water lost except through the occasional seams. If, on the other hand, it is in loose gravel, the entire flow may at first disappear in the course of a half-mile or more. In ordinary earth or loam, the losses are relatively small and may average from one to two per cent. per mile.

It is of the first importance for a manager of a canal system to ascertain by systematic measurements the losses which take place from point to point in the canals and to consider the relative cost of lining those portions of the canal where the losses are greatest.

These losses are best expressed in terms of the depth in feet lost in twenty-four hours through the wetted perimeter of the canal prism.[1]

They may vary from a depth of 0.3 foot in cement-gravel and hard pan to 0.4 in clay and clay loam and up to as high as 1.0 foot in sand and to 2.2 feet in sandy and gravelly soil. The effect of velocity in reducing seepage losses is shown in a certain instance where by increasing velocity from 1 foot to 3 feet per second, there was a reduction in seepage loss from 3.0 to 1.7 cubic feet per second per mile. To prevent all losses in one case, a clay puddle was put on a porous soil where, after two weeks of constant labor day and night and the expenditure of about $2,000, equivalent to about 10 cents per square yard, the canal was made perfectly water-tight. The necessity of this work and the resulting gain would not have been apparent had not good records been kept.

Canal Lining.—The lining of a canal or lateral, as above stated, may consist simply of a clay puddle or may be more elaborate and expensive, cement or concrete being used

[1] See article on seepage losses from earth canals by E. A. Moritz in *Engineering News*, Aug. 28, 1913, p. 402.

to render the banks impervious. The question of cost enters here and its relation to the benefits which may be received. While a concrete lining of from four to six inches in thickness is undoubtedly suited to some localities, yet the cost is practically prohibitory for general use, and less expensive devices have been tried. Among these are rubble walls set in lime mortar and plastered with cement mortar. Oil has also been used on some canals, mostly in California, but this stops only a part of the seepage and is not practicable for all localities.

Ordinary plaster applied to the walls of small canals has been effective in some places, but if not well drained the water gets in behind the lining and soon causes it to crack off. To remedy this condition the lining has been reinforced with ordinary mesh wire such as that used for garden fences or poultry runs. One large item of expense which is eliminated in this way is the doing away of the forms, wooden or metal, which make progress slow. The chicken wire is fastened to the sides and bottom of the canal or lateral with nails or staples made out of ordinary fence wire.

The principal difficulty in work of this class is to get the plastering done well as it requires careful inspection to see that the workmen work the cement in thoroughly. To overcome this difficulty the so-called " cement gun " is used, by which cement is shot under a pressure of approximately forty pounds to the square inch.[1] It is mixed as applied and leaves the nozzle at a velocity of two hundred feet per second, consequently there is no appreciable time between the mixing and laying and it is denser and of greater tensile strength than when applied

[1] See *Engineering and Contracting*, Apr. 1, 1914, p. 397.

by hand. The cement gun is operated by a small compressor driven by a gas engine, all being mounted in such way as to be easily moved from place to place.

Canal linings on which the mortar has been applied with the cement gun or by hand are feasible in open gravels which are common throughout a great part of the arid region. In this material as mortar adheres firmly to the irregularities of the gravel face, an excellent bond is insured and the openings of the gravel backing give sufficient drainage to prevent heaving from frost action. For sandy and loamy soil where greater thickness of lining may be required the ordinary method would undoubtedly be the better, but with the cement gun, where seepage through gravel is to be prevented, it appears that the mortar is driven more thoroughly into the interstices than is possible with hand work. In this way canal lining of from 1 inch to $1\frac{1}{4}$ inch in thickness can be placed at a cost of less than 7 cents per square foot, of which the greatest cost, or about one-third the total, is for cement. In any considerable length of canal where sand is accessible this cost could be reduced to 5 cents per square foot for a 2 to 1 Portland cement mortar with cement at not over $2 per barrel on the work.

There are almost innumerable ways of stating the cost of canal lining, the most important of these being by the square foot or square yard, or in the case of small distributaries by the linear foot. The thickness of the lining must always be considered at the same time and to make comparisons among canals of different sizes it is usually preferable to state the cost per cubic yard of material handled. As an example of costs under ordinary hand methods may be given the lining of a canal at Riverside, California, 2 feet wide on bottom and approximately 8 feet wide on top, 4 feet 3 inches deep, with concrete 2 inches thick on the side, and 3 inches on the bottom, the cost being about $1 per linear foot. On the Umatilla project in Oregon, as reported by H. D. Newell, the canal lining, 4 inches in thickness, has been placed by hand at a cost of about $7 per cubic yard including all general or overhead expenses. Where the smaller distributaries were cleaned and lined with 1½-inch cement mortar the cost including general expense was 50 cents per square yard, and where excavation was not necessary, about 45 cents per square yard—excellent results being had with thin mortar lining from an inch to 1½ inches in thickness.

WASTE WATER.—The record of the amount and character of the waste water is the most convincing evidence of the degree of care with which an irrigation system is being operated. The occurrence of waste water in any considerable quantity shows that somewhere there is carelessness or inefficiency. The loss is not simply that of the water itself, which may be in excess at that time of year, but it is closely connected with far greater loss, namely that of the fertility of the soil. This waste water usually carries with it in solution more or less of the valuable soil constituents which are needed in crop production. It frequently happens that the irrigator is not only robbing the soil by taking away the crops and not returning any of the organic matter, but at the same time he is diminishing the original fertility by washing or leeching out the soil, many of the soluble substances of which are an important part of the plant food. Thus in time there results an impoverishment of the soil, due to this double action of taking away from the surface and from underneath those substances which should be carefully kept or returned to the farm.

In some instances, where there is an excess of earthy salts, grouped under the general name of alkali, it may be desirable to apply water liberally and to wash out a portion of these salts. The resulting water can hardly be called waste water, however, as it has performed a useful function. The waste water which is of especial concern to the canal manager is that portion which flows away from the irrigated land, usually in small streams and at points below where it can be recovered or again used within the limits of the project.

The determination as to the quantity of water which should be applied to the field and the reduction of waste must rest largely on full information obtained by complete observations of the soil rather than by the superficial methods of judging from the general appearance of the crops themselves. In this respect, the irrigators who have had experience in other localities and under different conditions of soil and climate may be at a distinct disadvantage, as they are apt to base their judgment upon the general appearances without inquiring carefully into actual conditions. For example, one irrigator held up to ridicule the project manager who insisted on going to the field with a spade and digging holes in the ground to learn for himself as to the effect of the water on that particular soil. The irrigator claimed that he could judge from a distance of a quarter of a mile whether the crops needed water, or not. In this case, he insisted that water should be applied because of the appearance of the field, but the project manager on digging into the soil was quickly able to show him that the subsoil was heavily saturated and that the crops were not suffering for lack of water on the surface, but rather from oversaturation of a soil whose texture was entirely different from that with which the irrigator had before been acquainted.

Penetration by Water.—One of the most important matters for the irrigation manager and farmer to know is that of the depth of penetration of water in the soil. It is shown by Professor Hilgard that it is easy to ascertain this by taking a small iron rod of square section provided with a cross-handle, placing it on top of the soil, and twisting it slowly from side to side. The rod will descend through the saturated or wet earth and there is perceptible a decided resistance when the dry earth is encountered.

It occasionally happens that because of lack of knowledge of the depth of penetration an insufficient time is allowed for the water to soak into the soil, or not water enough is used; so that, for instance, trees especially may lack proper development, although the farmer believes that he has given them a thorough irrigation and has paid for enough water to do so.

It is absolutely necessary to know where the water goes which is applied to the surface of the soil, and this knowledge should be part of the common education of the farmer and irrigation manager. Instead of obstinately persisting in following along a certain line or imitating his neighbors whose soil may be different, each farmer should carry on for himself these relatively simple investigations and know what is really taking place.

For example, on one orange grove it was found that the water was penetrating to a depth of only eighteen inches, because of shallow tillage, and in another, very similar in appearance but well cultivated, the water was reaching to a depth of nine feet. The roots being limited in their development largely by the amount of moisture it is obviously of first importance to know the true conditions.

Decrease in Fertility.—One of the sources of deepest concern to the irrigation manager is the marked tendency of the irrigated lands to decrease in productive capacity. He cannot help seeing that many of the cultivated fields each year are yielding less and less. There are sufficient examples to show that with care it is possible to keep the yields above the average. These instances of success emphasize the fact that the majority of the irrigators are not utilizing the knowledge and experience of others to prevent waste and to increase the soil fertility. The decrease of productivity is due to several causes, the most notable of which are as follows:

1. Washing out the plant food by excessive use of water.
2. Swamping of lowlands, due largely to lack of care in applying water or to defective drainage.
3. Introduction of disease or conditions which are not as yet understood by the agricultural experts.
4. Neglect to apply fertilizers under the assumption that the irrigation water is sufficient.

Wasting Plant Food.—The evils of excessive use of water in irrigation are shown in the leeching out of soluble constituents of the soil needed by the crops. The soil of the arid regions in its original condition when properly irrigated will frequently yield largely, especially of the cereals, but in the case of somewhat open, porous soil, continued excessive application of water results in the carrying away beyond the reach of the plant roots many of the mineral or organic salts, leaving relatively little but barren sand.

It is evident that the material upon which every plant builds its life must be soluble in order that it may pass into the tissues of the plant, and while the action of plant life increases the solubility of some substances yet the same conditions which make the plant food available to the roots, make it easier to be carried away by an excess of water applied to the surface and escaping downward.

Swamping.—The excess amount of water applied in irrigation, loaded frequently with matter valuable for plant life, works its way through the more pervious strata or along the upper surface of less permeable layers beneath the surface of the fields. Drawn downward by gravity, it thus percolates vertically or is forced along the slightly inclined slopes of subsurface rocks until it reaches a natural drainage line, or appears upon the surface of low-lying lands. These lands receiving the waters by percolation are for the time being enriched; one or two large crops may be produced without the application of water to the surface. This increase in productivity is a danger signal as it is quickly followed by decline in plant growth, due to excessive amount of water which begins to reach the lowlands. Soon there is the appearance of wet spots on the surface or of bare patches of white or black alkali. These rapidly increase in size until what was formerly one of the most productive farms of the valley has become a swamp or an alkali flat.

In this way, a group of farms may be ruined through no fault of the owners, but because of carelessness of the neighbors on the higher lands, perhaps a mile or even two or three miles away. There appears to be no redress nor method of protection, excepting by the united efforts of all intelligent irrigators, first, in bringing about a state of public opinion such as will force a more economical use of water, and second, in the formation of drainage districts or organizations to build intercepting and other drains to relieve the situation.

Obscure Diseases.—As a result of an excessive amount of water and of the accompanying matter in solution which reaches lower lying lands, there may be for a time an increase in crop yield, followed by very puzzling conditions: the plants appear to be sick; there is nothing definite the matter, and experts vary in their judgment as to what is at fault. Insect pests increase or fungus diseases appear to prevail, yet all of the conditions cannot be directly attributable to these, as they appear to be a result, rather than a cause, of the general depression in plant vigor.

This condition has long been recognized. For example, in Egypt, it is stated:

Some years ago the government was inspired to increase the productivity of the soil in the Nile Valley by erecting an immense dam across the river at Assouan for the purpose of providing a more trustworthy irrigation. For ages past it has been necessary to depend upon the annual rise of the river to saturate the soil sufficiently for the production of crops. The great dam has unquestionably yielded enough moisture for all purposes, but for some reason which has been greatly worrying the authorities the cotton production which is one of the most important of Egyptian assets, has deteriorated. Indeed, as the dam has been raised and the amount of water impounded and distributed has increased this deterioration has progressed, the value of the production diminishing with the expansion of the area. It was at one time thought that the deterioration was due to the use of unsuitable land for cotton raising, but this was proved not to be true by the discovery that the crop yielded by unquestionably good land was steadily growing smaller. Sir William Willcocks, a widely known authority on irrigation, has just offered an explanation, which is causing grave concern in Egypt. The abundance of water, he says, has resulted in the appearance and multiplication of a worm which destroys the young cotton plant, possibly identical with the boll weevil which has been such a costly nuisance in this country. In the Egyptian agricultural system the ground is first planted to maize, for the production of which large quantities of water are used early in the season, this saturating the ground beyond the point necessary for the development of cotton. It furthermore stimulates a growth of clover on which the cotton worms are ready for attack. In the old days the hot dry summer killed the worm and the cotton crop was thus left to mature without molestation. Perhaps some way will be found to offset this disadvantage. The discovery, however, that Egypt is really suffering from a surplus of water is an unexpected development.

Another statement regarding the conditons which have prevailed in these irrigated areas is given as follows:

Probably the root cause of the disease is excess of water. The irrigation schemes executed by Lord Cromer were not altogether well designed, and the land is becoming waterlogged. A commission is investigating the problem and Lord Kitchener has taken up the work with characteristic ernergy.

Neglect of Fertilization.—There has been a current fallacy that the water applied in irrigation supplies all of the fertility necessary for plant life, as noted on page 26. This has been one of the stock arguments of men interested in the promotion of irrigation schemes as showing the superiority of irrigation over ordinary methods of agriculture. While a good irrigation system does have great advantages and while the muddy waters used in irrigation frequently carry valuable fertilizing material, yet dependence for maintaining and increasing the fertility of the arid lands cannot be placed wholly upon the irrigation waters. In Egypt itself, where the Nile mud had been typical of fertility, it has been found that manure or artificial fertilizers should be used and one of the problems before the British engineers, as above noted, has been that of obtaining an ample supply of phosphates and other essentials for plant development.

Studies made of the excessive use of water, notably on sandy soil, emphasizes the fact that it is really lack of fertility of the soil which is commonly responsible for unsatisfactory growth rather than the shortage of water. The importance of building up the soil by plowing under green fertilizers cannot be too greatly emphasized, not only to secure larger crop production, but also to bring about greater economy in the use of water.

Preparation cf Land.—The most frequent cause of waste of water is lack of proper preparation of the surface. The use of large irrigation heads and consequently quick and economical watering are possible only where the surface has been brought to a uniform gentle slope with all of the high spots taken down and the depressions filled. Much of the land in the arid region is left by nature in almost ideal condition with reference to the application of water, but other lands, especially the fertile, overflowed lower bench lands along some of the streams, are very uneven, due to the formation of small channels or gullies at times of extraordinary floods. Other higher-lying lands upon which scanty vegetation grows have been sculptured by the wind, which has left the surface in a wave-like form, the loose soil being heaped up around the clumps of low bushes.

The cost of leveling may range from two or three dollars an acre, where the work is easily performed by dragging a heavy iron bar or rail over the surface, up to as high as fifty dollars or more per acre on the rich lowlands where roots and stumps must be grubbed out and the entire surface reshaped.

It is evident that the ordinary pioneer farmer does not have sufficient money nor time to level up his entire farm in advance of cultivation, especially where the surface is undulating. Where the ground is not properly leveled, his efforts to irrigate the high spots result in drowning out the crops in the depressions and in waste of water. This is not only injurious to the farm itself, but frequently causes an excessive underground seepage, raising the water plane and destroying, as before stated, the agricultural land on lower ground at a distance. (See also page 90.)

On poorly prepared land, the farmer can rarely use more than one or two second-feet as an irrigation head, whereas on well-leveled ground, with some crops, he may use as high as ten second-feet or even fifteen, and can finish the irrigation of a field in one-fifth or one-tenth of the time otherwise spent in attempting to distribute the smaller head.

The gain in economy of water as well as time of irrigation is proportionally greater than would appear to result from the sizes of the irrigation head, that is to say, with two second-feet, more than five times as much water and time is required to produce satisfactory results than with ten second-feet.

The desirability of using large heads of water for short periods of time is beginning to be better understood. Commonly, a water user cannot immediately employ as large heads as he might, because the distributing system has often been built with the idea of a continuous flow, and for lack of funds the manager cannot at once make a change, but must do this gradually as means are available.

After once becoming accustomed to larger heads, the water users are usually better satisfied and, through rotation of flow during the hottest months, the rate of use on some of the irrigated lands has been cut in half with corresponding saving of time and energy on the part of the irrigator. From measurements made of water applied on sandy soils, it has been found that out of 6.6 feet in depth applied, 5.5 feet were lost by deep percolation. On other words, over 83 per cent. of the water was lost by soaking downward, leaving 16 per cent. available for plant growth.

Great quantities of water are lost when irrigation is prolonged unnecessarily. In a sandy soil it is probable that having water in a furrow from half an hour to an hour accomplishes all the good that can be done by a single irrigation. Keeping water in a furrow for ten hours or longer, as is frequently done, merely means loss of that water. In other words, nine-tenths of the water which has been applied is lost and may become a menace to lower-lying fields. The man who permits the stream to run for ten hours is not aware of the mischief he is doing, because the water is sinking down out of sight.

Alkali.—The most serious consequences following the lack of water economy are in the development of the so-called alkali salts on the surface of the ground. Merely water-logging or swamping of the land is comparatively harmless as the excess of water may be removed or its occurrence prevented. Unfortunately, however, this excess of water is accompanied by an accumulation of soluble mineral matter at or near the surface of the ground where it is most destructive to plant growth.

Most agricultural soils have resulted from the decay of more solid rocks. In this process of decay certain portions of the rock have been set free as salts, such as the common table salt, or chloride of sodium, which is found almost everywhere in small quantities. There are also found other common soluble minerals, such as gypsum or sulphate of lime. Various carbonates of lime and magnesium are also formed through rock disintegration. In the soils of the humid region the abundant rainfall tends to wash these away from the surface as rapidly as they are set free or are exposed, but in the soils of the arid region there is not sufficient annual rainfall to leech these out, and thus in its natural condition much of the ground of the arid West is impregnated with soluble substances.

These substances are fairly well distributed under natural conditions, so that samples taken from the surface downward show about the same amount for each foot in depth. This comparatively uniform distribution, however, is quickly modified by the artificial application of water, which, applied to the surface, works its way downward and dissolves the salts. The surface again drying, some of the waters charged with mineral matter in solution begin to return by capillary attraction and are evaporated from the surface, leaving the soluble material behind. This process is repeated and by a careless use of excessive amounts of water it may result in a few years that the greater part of the soluble minerals are pumped up to the surface by the water which has been evaporated and there is formed the white crust so familiar to residents of arid regions.

This crust known as white alkali consists largely of sulphate of lime or gypsum. While destructive to plant growth it is less dangerous than the so-called "black alkali" or bicarbonate of lime and soda. The appearance of either white or black alkali is often an indication of bad management or carelessness somewhere and it is the duty of the irrigation manager to be on guard to prevent it.

Wasteways.—In the ordinary irrigation system provision must be made for taking care of some waste water, as even with ordinary care there will be some water lost from the fields, especially during the years before the farmers have these completely leveled and before they learn to work in systematic manner. Wherever possible these waste ditches should be so arranged as to turn the excess water back into the irrigating canals, to be used on lower lands. If this cannot be done, connection should be made with natural drainage lines and these cleaned out and straightened to provide quick delivery to river or creek channels.

Efforts have been made in some irrigation systems of considerable size to get along without wasteways and to discourage the wasting of water by compelling each farmer to take care of any excess which may occur. Although this is theoretically proper, yet under pioneer conditions it is practically impossible to prevent some waste and the efforts to develop a new system without providing wasteways has generally resulted in great dissatisfaction. On the other hand, if the wasteways are made too convenient and prominent, there is always the temptation to turn an excess into them instead of handling the water more carefully on the land.

Drains.—A careful distinction should be observed between drains and wasteways for although the same conduit occasionally may be used for both, yet they are distinct in their purposes. The wasteway is to provide for the taking away of temporary excess of water flowing on the surface, while the drain is provided for the purpose primarily of keeping down the water table and removing the excess from beneath the surface.

The wasteway may be in operation only for a few hours or days, carrying away water which is not being carefully handled during the process of irrigation. The drain, on the other hand, usually discharges a relatively small steady stream throughout the greater part of the irrigation season, the water coming to it slowly by percolation after the fields have been irrigated, the drain continuing to discharge water for some time even after the crops have been removed.

Wasteways are usually relatively shallow ditches and, as before stated, may lead into lower-lying irrigation canals or laterals. Drains may be open or covered, and, depend for their value largely on their depth beneath the surface. Being deep, it is usually necessary to cover them over as otherwise if the banks are greatly sloped to prevent earth falling in, the width of the top of the drain is very great and requires an excessive amount of land.

Drains are usually excavated to a depth of six or eight feet, the depth being determined in advance by thorough investigation of the character of the subsoil.

There is no one feature of irrigation engineering practice which appears to be more self-evident or easier of solution than the location of a drain; on the other hand, there is probably no one item of expense in which more money has been wasted than in the building of poorly located drains. The ordinary observer, looking at the ground, determines immediately from the appearance of the surface that the drain should be put in a certain direction, and public opinion decrees that this is the proper course. After it is built, however, for some reason it does not give satisfactory results; then inquiry is made as to what is the reason. It is found that the drain does not draw down the ground water as anticipated and evidently there are some underground conditions which were not known. To ascertain these, it is necessary to put down a series of test pits or drill holes to obtain samples of the underlying soil and to learn what are the true conditions.

The experienced irrigation manager, in view of the condition just described, studies the underground conditions before the drain is built, even though the proper location may appear to be self-evident. It may be necessary to delay construction to obtain the essential facts, but in the effective management of the project one of the first questions to be inquired into is that of the behavior of the ground water. Small shallow wells or pipes driven into the ground should be located at important points and observations made one or twice a month of the rise of the ground water, the results being studied in connection with the figures showing the time and quantity of water applied to the surface.

It will usually be found that there are a number of peculiar phenomena. For example, on the Shoshone project, Wyoming, the land surface slope is about twenty feet to the mile. Under the surface at a depth of from four to eight feet or more is a thick bed of coarse gravel. The ordinary observer or even the agricultural expert would say, as has been said, that with this slope and underlying conditions, it would by impossible to swamp the land. The water would either run off the surface quickly or, getting into the gravel, work its way downward to the deep river gorge. Acting under this assumption, an excess of water was applied and in the course of two or three years considerable areas of land were swamped. A study of the underground conditions by means of numerous small wells showed that certain portions of the gravel were nearly impervious and that drains located according to the surface slope alone did not effectively relieve the conditions.

By locating the drains in such way as to cut through certain impervious bands or ridges of gravel, immediate relief was had and the water plane drawn down. In other words, a knowledge of the subsurface conditions brought about a location of drains entirely different from those which would have been dug by observation of the surface conditions only.

It is usually impossible to estimate accurately in advance the outlay which will be necessary in any irrigation project in providing necessary drains. In planning the distribution system, wasteways may be located and their probable cost ascertained, but the matter of drainage involves so many uncertainties that estimates in the past at least have been unreliable.

Theoretically, it should be possible to make a thorough study of underground conditions by means of test wells or borings and from the results of observations of these, lay out a drainage system. The cost of this preliminary examination, and the delay involved in making it, is such as to deter most investors. More than this, the estimated cost of a complete system of drainage may be so great as to prevent the enterprise being undertaken.

The usual attitude of mind of the persons promoting irrigation works is that "where ignorance is bliss, 'tis folly to be wise," and that in any event the needs of drainage will not be felt until irrigation is developed to a point where the land values will be sufficiently great to justify taking up the building of the drains; or, to put it in another way, the need of drainage gradually developing will be met by the farmers from time to time acting in coöperation, or by organization of drainage districts.

Keeping Water Out of Drains.—Because of the peculiar construction of the drains, there arises the necessity of taking especial care to protect them from misuse. The most serious menaces are: *first*, wasting into the drains of surface waters, and, *second*, excessive seepage due to the construction of portions of distributing systems or of waste-water channels too near drains.

Instances have been noted where irrigators of lands bordering upon drains permitted waste water from the surface of the land to flow into them. Where the drains are open there results a washing of the earth from the banks and partial filling or obstruction, thus reducing their effectiveness. Where the drains are closed and water is allowed to accumulate or stand over the buried pipes, the result is saturation of the soil above the pipe and a downward flow tending to carry sand or fine material into the pipes. Instances have also been found where small laterals have been constructed on the banks of open drains or directly over the top of a drain pipe. The result is to produce excessive seepage or danger of breaks.

The filling over a buried drain should be kept well rounded up to prevent water from standing or flowing across it. No lateral or waterway should be placed less than thirty feet from the center line of the drain. If it is necessary for these to cross a buried drain, this work should be done in such a manner as to reduce the seepage loss as much as possible, notably by building tight flumes over the point of crossing or by carefully puddling the earth until the filling over the drains has become thoroughly compacted. It is necessary to exercise great care in order to prevent holes being opened through the loose earth into the drains.

Pumping.—The possibilities of water economy are best illustrated under conditions where the supply is obtained by pumping. Here it is plainly evident that every acre-foot of water lifted is costing a certain amount of money, in fuel or in labor and in the wear of machinery. With a gravity supply, such as is provided for most of the irrigated lands, this expenditure is not so immediately evident; but in a pump supply the irrigator is continually alert to keep down this daily cost. As a result he will manage to get along with half the water which he considers essential under the gravity system. Although pumping has been used, and will probably be used, for only a small percentage of the lands irrigated, yet it has an unusual importance because it makes possible the lesson of water economy. Pumping is not only utilized in bringing water to the land, but also in taking the excess away and in keeping down the water plane in localities where drains cannot be economically constructed.

CHAPTER IX

MAINTENANCE

THE maintenance of an irrigation system presents problems quite distinct from those connected with its operation or even with the original building of the works. Maintenance is essential to proper operation, also it is closely allied to construction; in many cases it is a prolongation of the latter and there is difficulty in drawing a sharp line between what may be called the original work and that added later during the gradual evolution of parts. Some structures built as a necessary part of maintenance were contemplated from the beginning though not finished at the time of the original work. For example, in the case of the enlargement and repair of a headgate, certain portions were completed as part of the first construction; foundations or spaces were then left for additions such as might be needed in the course of systematic development of the irrigated project. Later these were inserted as part of the maintenance of the systems, although in one sense they were in completion of the original plans.

It is necessary, in considering maintenance and in classifying expenditures, to draw a somewhat arbitrary line between what may be called (*a*) the primary construction and (*b*) the secondary additions, the latter being essential to the growth and development of the irrigated lands. The same difficulty is encountered in attempting to make a fair division between the expenditures for operation and for maintenance. Although the purposes are in themselves entirely distinct, yet the work may be classified sometimes under one head or under the other, especially as it frequently happens that for economy the same body of men may be engaged at one moment on the work of operating and at another time on that of maintenance.

DEFINITIONS

The items of the expenditure included under the head of maintenance of an irrigation system, are those growing out of the keeping of the works in good condition, as distinguished from those expenditures of time or money which have to do with delivering water to the land. The cost of cleaning the canals and repairing structures is properly chargeable to maintenance, while the cost of turning the water on and off and of keeping the record of the time and quantity delivered is properly chargeable to operation.

The same man or gang may be employed both on operation and on maintenance; that is to say, a canal-rider whose business it is primarily to see to it that the water is turned into the laterals and to the farms may spend part of his time in removing weeds or other obstructions or in making temporary repairs. Under a careful system of costkeeping a certain proportion of his time may be thus charged to maintenance. Most maintenance work, however, is done immediately before or after the irrigation season and when the water is out of the canal, so that it is often relatively easy to distinguish between operation and maintenance by considering the time of year in which the given expenditure is incurred.

The amount of time and money which can be spent on maintenance is more largely governed by the judgment of the manager than is the operating expense, because of the fact that neglect of the maintenance is not as immediately noticeable as failure to operate the works properly. If they are not operated systematically and effectively, there is immediate complaint, but the maintenance may be neglected for possibly a year or more without immediate or serious consequences. The only way to ascertain whether the maintenance is effective is by frequent inspection or by taking account of stock, as it would be termed in other mercantile operations, to determine whether the works in hand have increased or decreased in value.

It is this difficulty of ascertaining whether the maintenance is effective or not which has led to much misapprehension as to the true cost of maintenance. The careful manager will expend considerable sums of money in keeping the canals clean, the structures in excellent condition, and be prepared to meet any emergency. The result, however, is not always apparent, because with a smoothly working system there are no comments called for, as it is to be supposed that the manager would keep the system in good order.

On the other hand, the manager who is desirous of making a record for economy may reduce the expenditures for maintenance, and let the canals and distributing system gradually fill with silt or the structures become weak. If in time of unexpected flood or cloudburst some accident occurs, it is then attributed to natural causes, rather than to neglect of the details of maintenance. It is only by careful study of the situation by competent and impartial men that it is possible to ascertain from year to year whether the maintenance is as thorough as is necessary for effective results. In other words, the condition of the entire system must be known at short intervals in order to ascertain whether it is possible safely to reduce expenditures for maintenance and whether there has been true economy or merely the withholding of necessary work until an accident occurs.

BETTERMENTS

Closely connected with maintenance is a class of expenditures which is likely at all times to give rise to much discussion; that is those items of outlay which tend not merely to maintain the irrigation system in its original condition, but gradually to improve it. For example, when the system is first built under pioneer conditions it is usually most economical to build many of the structures of wood, as at that time there are many unknown conditions and freight rates on cement and iron are usually high. Later on, when the wooden structures decay they may be replaced either with similar wooden ones in which case the cost is charged to maintenance, or with more permanent steel or iron structures, in which case the excess cost over the wooden replacement may be charged to betterments.

In the same way, the canal system as originally built may be constructed of minimum capacity, with the idea of ultimately enlarging it as the demands for water increase. It is frequently not economical to build a canal full size at first because for several years it is not called upon to carry a full supply of water and with reduced velocity due to small demands the canal tends to be rapidly filled with sediment, whereas, if built of small size it can be more easily kept clean. If such a canal when being cleaned is increased in capacity, the cost of the cleaning to the original size may be considered as maintenance and the added expenditure to bring about increased capacity may be charged to betterments.

The distinction between these two classifications can usually be made only at the time when the results of the work are fresh in mind and when it is possible to make a careful apportionment of items of expenditure for labor and materials. It is quite important that some such distinction be made in order that the owners or management of the canal may know how much has been paid out for the ordinary maintenance comparable with that of other systems, as distinguished from the gradual improvement of the property.

REPAIRS TO CANALS AND LATERALS

The repairs to an ordinary canal in earth consist largely in replacing portions of bank which have become eroded or in removing the sediment resulting from such erosion. Here the problem of maintenance is similar, on a small scale, to that of bank protection of rivers. Under natural conditions the current of most rivers swings from side to side, cutting the bank on one side and carrying the eroded material for a short distance, dropping it to form bars; then, gaining force, the water attacks the opposite bank. If the point of attack can be adequately protected so that the water cannot remove any considerable amount of earth, it is evident that there will be little to be deposited at lower points along the stream.

The same conditions prevail in an artificial channel, although to less degree, if the slope and consequent velocity have been correctly determined in advance of construction. With increased demand for water there is apt to occur at one place or another velocities such that the banks are attacked and, if the material is particularly soft, the erosion takes place unless protection is afforded by the growth of willows or similar plants or an artificial shield is made by placing at the point of erosion sagebrush or branches of cottonwood, willow or other bushes, holding these down with stones or wires.

These repairs may be made during the field season or if relatively small in importance they may be left until the water is out of the canal and more easy access is had to the places which need attention.

CLEANING

Cleaning canals and laterals may be distinguished from repairs as being necessary usually because of the fact that the velocity of the water at various points is less than that needed to keep the muddy water from depositing its load. Theoretically, a canal and distributing system should be so planned that any muddy water received at the head is carried along at a certain velocity until it is delivered to the fields of the farmers. As a matter of fact, however, it is rarely possible to maintain this velocity and at various gates or checks the water becomes still and more or less sediment is deposited.

In the case of canals taking water from rivers which during high floods carry excessive amounts of sediment in suspension, it is impossible to maintain a velocity sufficient to keep this sediment from being deposited. such, for example, as in the case of canals from the Rio Grande or Colorado rivers. The fall of the country does not enable canals to be built on a grade steep enough to prevent sediment being deposited from flood waters. If such grade is possible, excessive erosion would result at other times. It is necessary, therefore, to provide as far as practicable certain sand traps or sluices to take as much as possible of the sediment out of the water near the head of the canal and systematically clean out the entire system once or twice a year, or even oftener, as the mud accumulates.

Employing Farmers.—In small privately owned systems the individual landowners combine to do this cleaning or divide it among themselves, each man being responsible for a certain portion of the system. On larger canals efforts have been made in a similar way to have the farmers living under the canal do this cleaning by contract. As a rule, however, this has not been wholly successful because it is frequently necessary to have cleaning done at the time when the farmer should be occupied at home. It is also extremely difficult to make a contract such as to be enforceable against the individual who does this cleaning incompletely or poorly, as the cost of inspecting and measuring up the work to prove lack of thoroughness is a notable proportion of the cost of proper cleaning. When, therefore, the individual interest of the farmer is not sufficiently great to lead him to do a thorough piece of work, it is usually impossible to let contracts to the farmers with any considerable degree of success.

Efforts should be made, however, by managers to furnish employment in cleaning and maintenance work to the farmers or residents within the area covered by the project. Although experience has shown as above stated that it is usually quite difficult to secure the labor of farmers in the critical times when repairs are needed, yet a better spirit is engendered if it is understood that preference will be given to farmers in such employment. It is essential, however, to have a small gang of men regularly hired and to increase their numbers as necessity arises by employing the farmers by the day.

It has been asserted by some canal managers that in this heavy manual work of cleaning ditches, the labor of the average farmer is not as efficient as that of the ordinary day laborer, as the farmer is not accustomed to work in gangs or consecutively at such heavy work. It has been pointed out in the publications of the Department of Agriculture that although farm work is usually hard and the hours are considered long, yet as a matter of observation it appears that the average farmer does not put in eight full hours of effective work and that the majority are not accustomed to a daily routine of sustained physical effort such as is required in cleaning the canals. In the old days of pioneering, all of this work as well as that of building the irrigation works was performed by the farmers themselves, but it is generally rcognized that these men, driven by necessity and selected by their ability to endure hardships, were above the average of present settlers as far at least as physical strength is concerned.

On the newer projects where a miscellaneous population has flocked in from all parts of the world, there are apt to be many disappointments to the manager in securing labor for such work as cleaning. The men who are competent are usually too busy on their own farms, and the others who are in evidence at the corner grocery or who have apparently little to do, cannot readily be induced to take up the necessary work, although their families need the wages. Thus the condition is not unusual where it is necessary to bring in labor from outside to perform in an efficient and economical manner the work which theoretically might be done by residents of the community.

In the same way that it is necessary to have a small body of laborers to be depended upon in times of emergency, so it is often necessary to own and maintain enough horses to have at all times a small outfit to insure that the needed work is performed. This expense may at first appear doubtful because of the fact that the horses are needed perhaps only three months out of the year, but these are the months when the farmers cannot spare their teams.

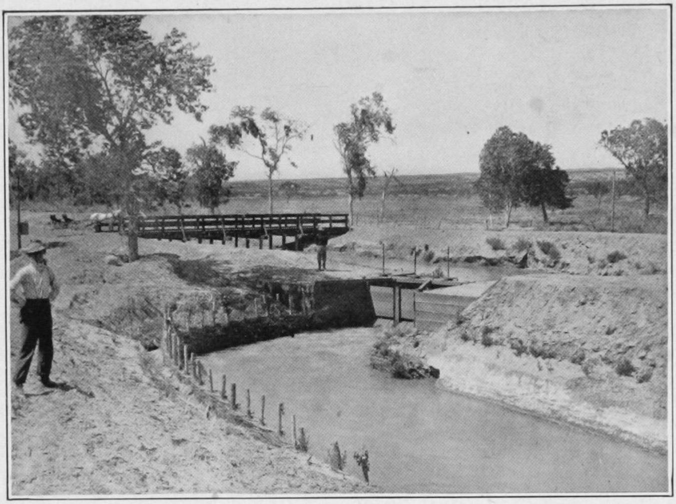
Whenever conditions appear to be such that good results can be obtained by making contracts for cleaning out a canal at a fixed rate or unit price, there may be economy in so doing. Payment should be made after inspection of the work and acceptance when in full accord with the specifications. A small bond for faithful performance of the work should be required, and a time limit set for completion with forfeiture of so much per day for failure to complete. Without such bond and forfeiture, the average man is apt to put off the work and finally seek to excuse himself if the weather is not propitious or other conditions turn out to be not as favorable as he anticipated.

REPAIRS OF STRUCTURE

As distinguished from the relatively simple but laborious details of cleaning canals and repairing earthwork, the maintenance of structures requires the employment of a certain degree of engineering and mechanical skill. Many of the earlier and smaller structures on most distributing systems were built of wood in order to save expense, as at the time of building the transportation facilities were not perfected; also for some years after initiating the work the structures are not needed of full size. Thus it was frequently a matter of economy to build them smaller than would be ultimately needed, with the intent of renewing or enlarging them when the time arrived that the irrigated lands were more largely utilized, as by that time the wood will probably have become decayed.

The replacement of the wooden structures by concrete and steel may be carried on systematically as part of the necessary repairs and the extra cost of enlargement and of substitution of more permanent material may be considered as betterment of the system. (See page 144.)

At the time of renewal many questions which were in doubt at the time of the original building of the works have become more nearly settled, such, for example, as the amount of water required for the land and the consequent capacity of the structures. When first planned it was necessary to assume a certain duty of water but after use for about five or ten years some of the lands may have become saturated to a point where far less water is needed than was at first anticipated, and it is found not necessary to build the structures as large as originally assumed. On the other hand, it may be found desirable to extend certain portions of the system to take in other lands and thus the structures must be increased in size. In short, the repairs which must be made from time to time are based upon a revision of



Wooden Headgate of Lateral with Brush Bank Protection.
This prevents erosion and silting of channel at down points.

Betterment of Main Canal.
Enlarging by dragline while canal is in operation, in Salt River Valley, Arizona.

the early plans and better knowledge of the conditions to be met.

PROTECTION OF SANDY BANKS

A large item of expense in some of the main-line canals is that arising from the sandy nature of the soil and the ease with which it is eroded. The wind on the surface of a broad canal creates waves of considerable size and on long stretches exposed to the sweep of the wind, the wave action is serious. Constant vigilance is required in watching for wave-cutting, especially on the outer bank of the canal, and protection must be afforded temporarily by sand bags and more permanently by brush and stone.

One of the problems of the manager is to procure at reasonable expense suitable material for protecting these sandy banks. Stone is usually absent from the neighborhood and the cost of bringing it is prohibitive. Willows, cottonwood and pine branches and sagebrush are usually the most available materials. The branches are laid where the waves are cutting the sand with the butts placed downstream and the mat thus formed is held in place preferably by barbed wire fastened to stakes driven into the bank. (See illustration.)

A good example of successfully overcoming unfavorable natural conditions is that of a large canal taking water from the North Platte River in northwestern Nebraska, and which has been built for many miles on sandy hillsides. The maintenance of this canal brought with it many difficult problems, successfully overcome by the energy and devotion of the manager, Andrew Weiss. Quoting freely from his description, it may be stated that the protection against wind erosion was one of the most serious items of expense of maintenance of fifty miles of the main canal. It was not uncommon for an unprotected portion of the canal bank with a twelve-foot crown to be lowered three feet in vertical height within a period of six months if left unprotected against wind and the range stock.

Practically every means of canal bank protection proves a failure if range cattle are allowed to roam freely upon these banks. Not only do they destroy what little protective vegetation may grow, but they also loosen the banks by trampling so that the wind action will immediately remove the loosened portion of the soil, thereby causing rapid destruction of the bank. To keep out the cattle it was necessary to fence a tract about five hundred feet on each side of the center line of the canal. Prior to the building of this fence the adjoining sand drifts would blow into the canal during every winter and spring, so that much cleaning was necessary. Since the fence has been built for four years the sand hills within have become covered with sand grass and other protective vegetation and the drifting into the canal has entirely ceased. This is a most striking illustration of what fencing does in such places. While outside of this fence the ground is covered with barren, glistening sand drifts, the ground within the inclosure is covered with grass and the canal is effectively protected.

Since 1909 a total of 53 miles of 4-strand wire fence has been built, which together with private fences along the right of way, incloses all those portions of the main canal right of way for which protection is at all essential. The cost of this fencing was $75 per mile for material and \$50 for labor, or a total of \$125 per mile. While fencing is of prime necessity in order to make any scheme of protection effective, there are still many banks which are so loose that vegetation will not take hold unless additional protection is provided by persistent effort.

In October, 1909, 12,000 linear feet of newly repaired bank was covered with a light coat of stable manure at a cost of \$180. This was in fair condition on March 1, 1910. By August, 1910, nearly all of it had disappeared because of the high winds and a few head of range stock which found access to this bank. Manure covering was shown to be a failure except as a temporary means of protection and then only if stock could be kept entirely off the bank. In any case it requires frequent patching and renewal, because the wind will soon cut holes through it and begin to undermine the cover and gradually carry it off. Straw covering has been tried with similar results. To be of use, it must be spaded or disked into the ground or weighted down with earth; with these precautions it forms a temporary protection.

The best method, but also the most expensive, has been to put gravel on the top of the banks and on the outside to a depth of from 3 to 4 inches. About 44,800 linear feet, or 8½ miles of bank, has been protected in this way since May 1, 1909. This required a total of 11,800 cubic yards of gravel at a total cost of \$9,500, or a unit cost of 21 cents per linear foot, or 81 cents per cubic yard. Gravel has proven to be the most permanent protective coating to the banks, and is used whenever it can be obtained within a distance of 1½ miles.

Brush has been used to cover the outer slope of the banks in some places, where gravel or other protective material could not be obtained at a reasonable cost. About one-half mile of bank has been covered in this way at a cost of about 20 cents per linear foot. This has been quite satisfactory both for holding the bank and for catching drifting sand, but it is not safe on account of danger from fires.

Russian thistle (or tumble weeds) have been used successfully in covering the banks to prevent wind erosion. Two methods have, been used in putting on a weed covering—one is to hold the weeds down with woven wire, and the other is to weight them down by throwing some earth on top of them.

In the former case a single or double width of hog wire (48-inch wire rolls) have been stretched over the outside slope of the bank, staked to the ground and thistles filled in underneath. This has proven satisfactory, not only in stopping erosion and promoting vegetation, but also in strengthening the bank by catching drifting sand. It has also another advantage in that it can be put on banks too narrow, too steep or too ragged for any other means of protection. Approximately 5 miles of bank have been covered in this way at a cost of 11 cents per linear foot, 4 cents for wire and 7 cents for labor. As the average width is 9 feet, the cost per square yard is also the same.

The latter method (weeds without wire) is used where the banks are in reasonably good condition or where they have been recently repaired. Where the slopes are flat the weeds are generally plowed in. This is done by commencing with a plow furrow near the bottom of the slope, filling it with weeds, plowing a second furrow about fifteen inches higher up, and turning it down over the weeds below and covering them one-half up; and in this work continuing on up the slope. On steeper slopes or in small patches, the weeds are usually placed and a shovelful or two of earth thrown on each weed as the work is carried up the slope is generally sufficient to hold them down. This method has proven satisfactory in holding the bank and also in getting the banks matted over with a growth of new weeds. Approximately 60,000 square yards of bank surface have been protected in this manner at a total cost of $3,700, or 6.1 cents per square yard.

During October, 1912, experiments were made on coating a sandy portion of the canal bank as follows:

Kind.	Area Treated Square Yards.	Cost—Total.	Per Square Yard.
Cement coating	144	14.14	.098
Calcium chloride (500 lbs.)	180	20.43	.114
Crude oil	430	41.14	.096
Sugar syrup (5 bbls.)	435	34.42	.079
Coal tar	300	20.36	.068

Of the above the crude oil afforded the best means of protection; the calcium chloride proved worthless; the sugar syrup is of little value, because it dissolves in the rains. The cement coating breaks up and the sand begins to blow from between and underneath; and the coal tar, which is the most effective next to the crude oil, was impracticable of application, because of the very limited supply obtainable. Furthermore, the coal tar had a tendency to run in the hot summer weather, and afterwards it scaled off. On account of the prevalence of Russian thistles in this section, which pile up in the canal during the fall and winter months when the canal is not in use, these were found to be the most useful means of any to protect the banks.

Slides.—Wherever a canal is built in earth along a hillside, there is necessarily introduced a change in natural conditions, and time is required to bring about a relatively stable adjustment. The original slope has been the result of centuries of carving by the wind and rain and of adjustment of load. It may be on the verge of unstable equilibrium, just ready to slip, lying at what is sometimes called the angle of repose. The throwing of an additional load of earth on one side or another may bring about such a disturbance as to start the earth sliding either gradually or rapidly. Even during construction there may be noticed a settlement along the hillside.

The greatest factor in disturbing natural conditions is that of the introduction of water, which, saturating the earth, not only shifts and increases the weight on the hill slopes, but in a way lubricates the earth and facilitates the slipping of one layer upon another. The slides may be into the canal from the steep slopes above or more generally away from the canal, the lower saturated bank sinking and permitting the water in the canal to escape.

The slides from above into an irrigation canal are similar in many ways to those on a large scale on the Panama Canal, and arise from the same varieties of causes. Usually they are the result of removing the support from the lower side of the slope and of weakening the adhesion of the upper layers of the slope by the introduction of water, which softens the supporting material. There are certain fine clays which receive and transmit water slowly and which, when thoroughly wet, will flow even on gentle declivities. A canal cutting through these clay beds and bringing water to their lower edges will almost invariably be obstructed in time by sloughing in of the clay beds which will not cease moving until the upper slope is perhaps as flat as one foot vertical to twenty horizontal. Beds of sand and gravel or of surface débris gradually work downward into the canal, due to the lack of cohesion of the particles, the movement continuing until the surface assumes a slope of one foot vertical to four or five horizontal.

The injury and resulting expenses from the sliding of material into a canal are relatively small compared to those where the lower bank tends to slip outward. In the first case, the flow of water can be maintained by frequent cleaning out of the material which falls in, but in the latter case the whole system is jeopardized, and the water in the canal which is needed for the irrigation of hundreds or thousands of acres of land is diverted to the destruction of lands and homes.

Where the lower banks are unstable and show signs of slipping, it is necessary to take every possible precaution and to maintain daily, if not hourly, watch for any signs of weakness—especially during the first few months or seasons after the canal has been put into use. It is assumed that in the construction of the lower banks great care has been taken to avoid slides by keeping the canal prism well in the natural ground and by compacting the material to be deposited upon the lower bank. The chief danger, however, lies usually in the fact that the original undisturbed soil may have been in a condition where it was pervious to water and nearly ready to slip. Under such conditions the additional weight of the excavated material deposited on the lower bank, and the softening of the lower layers by percolating water, renders the whole area unstable. It is only by carefully admitting water to the canal and watching the conditions, that it is possible to determine whether additional work must be undertaken to prevent slides or whether by careful handling the banks will gradually settle into a permanently safe condition.

The prevention of slides usually calls into play all of the ingenuity and experience of the irrigation manager. A method adapted to one kind of ground may not be advisable in another. Usually the first step is to attempt to drain the lower part of the slope where conditions appear to be bad and put a blanket of gravel or similar pervious material on the lower toe to hold it down and to counteract the tendency to slide by offering a support to the soil which is pressing down toward the bottom.

Sometimes a thin puddle lining of the canal may be advisable, in connection with the protection of the lower part of the slope, so as to obstruct the percolation of water into the bank. At the same time drains are provided for carrying away as much as possible of the percolating water. In other words, the lower bank should be kept as nearly dry as possible, as in this condition it will slip less readily than when wet.

The driving of piles or the buttressing of the lower part of steep slopes has been attempted in places, but with relatively small success on account of the difficulty of finding good supporting ground for the piles, or, if this is found, it is discovered that the weight of the moving material is so great as to displace any ordinary line of piles or other supports. Sometimes, as a last resort, it may be found necessary to put the canal in a tight flume along the points where the lower banks are sliding and thus carry it over these treacherous spots.

Combating Pests.—There is a never-ending warfare between the irrigation manager, aided by his assistants, and the innumerable animal as well as the plant pests which live along or under the canal system. The newly built banks offer tempting places for work of borrowing animals and a single gopher or muskrat in a few hours may dig a hole affording an outlet to the waters of a canal, which increasing during the night, will sweep away thousands of yards of earth. The trapping and poisoning of these animals must be carried on continuously until the banks have become consolidated through months or years of settlement. Even then vigilance should not be relaxed, but the canal-rider should be always on the watch for any disturbance of the earth by burrowing animals.

Each canal-rider should be provided with suitable traps and from time to time put out poisoned grain or bait in localities where indications of these burrowing animals are noted or where they are even suspected to exist, protecting this poisoned grain carefully, of course, from being found by domestic animals or human beings.

Vegetation on Canal Banks.—The best protection for canal banks is that afforded through the growth of vegetation, grasses, weeds or bushes and small trees, such as cottonwood or willow, whose roots hold the soil in place. Some of this vegetation serves a useful purpose in this way, while other varieties are highly injurious by tending to clog the canal and preventing the free flow of water or by dropping seeds into the water, these being carried out on the fields of the farmers and thus spreading noxious weeds.

The irrigation managers should study the character of vegetation which occurs naturally along the canal banks and if necessary introduce plants or sow seeds of such useful plants as may take root under the prevailing conditions. Various experiments must usually be undertaken to determine the relative cost and value of different grasses for use in this connection. Before undertaking these experiments, results of similar work elsewhere should be considered. On various canals there have already been tried the sowing of barley, rye and similar cereals and the cost of planting and cutting these has been compared with the similar cost of cutting and burning ordinary weeds.

By careful observation of the vegetation which occurs naturally and by comparison of costs of various methods of cutting or controlling the weeds, it is usually possible to arrive at conclusions for each locality as to the best method of treatment. There is as yet no one definite method adapted to the varying conditions of large and small canals and the different climatic conditions, nor is it always possible to draw a sharp line between the useful and injurious weeds which occur along a canal, as some of these weeds most valuable in holding the earth under certain conditions become highly destructive under others.

The destruction of the weed pests afford almost continuous occupation; especially in the South they spread with great rapidity along the canals and in the case of moss in the canal, or of large weeds on the side, the growth in a few weeks may be such as to materially reduce the flow of water.

Sheeping.—Wherever suitable inclosures or herders can be provided, such that sheep, goats, or cattle can graze on the banks of the canal, they are sometimes quite effective in keeping down noxious weeds. This is the case particularly with sheep, experiments with which have been made in the Salt River Valley of Arizona.

It was found there that the use of sheep has not only decreased the expense of cleaning Johnson grass from the canals and laterals but the packing of the banks has practically eliminated all gophers. It is estimated that leakage and breaks from that source have decreased at least ninety per cent. The maintenance foremen have commented upon the small amount of work required to maintain the laterals when sheep are used for cleaning purposes as compared with the greater amount of work, trouble and expense incident to cleaning the same laterals in former years.

Two herders have handled from four hundred to five hundred sheep. They experienced only a small amount of trouble in keeping them out of cultivated fields. This number of sheep confined to a canal bank means a line from fifty to one hundred yards long.

Johnson grass is unquestionably an excellent feed when young and tender and the sheep are also fond of the seed. Its feeding value is high and the sheep prefer it to most other plants except alfalfa. Sheep also relish the following plants that grow on the canal banks: sunflower, milkweed, sour dock, sour clover, bird clover, Bermuda grass, salt bush, young cockle burrs and most tree leaves, including the willow. They will not eat the so-called "tree tobacco," thistles, foxtail when headed out, and water grass when large.

The result of the experiment developed the following facts:

(1) That Johnson grass, the most dangerous pest on

the project, can be controlled and eventually eliminated from the bank of canals and laterals by the use of sheep.

(2) That the use of sheep has decreased materially the cost of cleaning canals and laterals.

(3) That sheep drive out gophers and thus cut the cost of repairing breaks and reduce the loss of water by seepage to a minimum.

(4) That it is profitable for the farmer to maintain his farm ditches with sheep.

(5) That Johnson grass will fatten sheep in ninety days; and

(6) That sheep can be pastured on the canals and laterals without damage to the banks.[1]

The cost of maintenance of canals and laterals before the introduction of the sheep was in round numbers $150 to $200 per mile. After the sheep were used the cost per mile decreased in each case fully one-half. The labor cost in handling the sheep was $1,500 and the saving in canal maintenance was estimated at $4,500. After proper allowance for various expenses connected with the handling of the nearly 1,500 sheep there was a profit of a little over $3,000.

Moss.—In many canals carrying clear water the growth of aquatic vegetation, especially the so-called moss, is a serious matter. It is necessary to incur considerable expense in keeping this down and in some localities extraordinary difficulties have been encountered, necessitating the shutting off of the canal and permitting the ground to dry out, even at the risk of loss of crops.

In the case of the Bear River Canal, in Utah, it is stated that the moss has been practically eradicated in

[1] From report of C. H. Fitch, Manager, and A. J. Holton, Superintendent, U. S. Reclamation Service, for year 1913–1914.

three years by using a disk harrow. This implement is stripped of seat and double trees and the tongue cut to four feet in length. To this are hitched two ropes, one leading to a team on each bank. By adjusting the length of these ropes, the harrow can be run on each slope or in the bottom. It is claimed that this digs up the roots and that they float down with the moss and are removed. Originally these canals were foul and the first year it was necessary to go over them three times in this way; the second year, twice; and now they require cleaning only once each year. Little moss is left and it is believed that this method may operate successfully in other localities. It is cheaper than attempting to mow the moss; it does not interrupt the flow of water in the canal; and also helps to puddle any leaky portion of the canal. It is possible that with a cross-beam and wheel on each bank the disk harrow might be dragged more satisfactorily.

Others devices have been tried for getting rid of moss; for example, by dragging heavy chains or similar weights along the bottom of the canal, the chain catching and dislodging the moss or pulling up the weeds by the roots. There are also various mowing machines which have been adapted to this work, some of which are fairly successful. It is to be noted in this connection that the moss flourishes best in clear water, and that if the water is muddy for any considerable length of time, the moss does not flourish.

Alkali Action on Concrete.—In certain soils, concrete structures, especially the thinner portions, are affected by the action of alkali contained usually in the water. The concrete gradually softens at the surface and crumbles away. Most of the injury occurs where seepage water percolates through the paving and the side walls of structures. Frequently the action may be delayed by proper use of drains and weep holes. In each case special study should be made to determine the best materials to be used in waterproofing or protecting the concrete or in replacing it, using cement or mixtures which are found by experiment to be least affected by the alkali peculiar to that locality.

Investigation made by the United States Reclamation Service has shown that the principal salts acting to produce disintegration are the sulphates, and especially magnesium and sodium sulphates. It is thought that of these the former is the more active, but this has not been definitely established. Different localities have shown different results for the same materials. Two extreme cases may be cited in the Sunnyside, Washington, and Belle Fourche, South Dakota, projects. A number of test specimens exposed on the former were observed at the end of about eleven months, but no disintegration, with the exception of a specimen containing a soap and alum solution in the mixture; the specimens were all of a 1 : 3 : 5 gravel mixture. Furthermore, none of the concrete structures on this project has been affected.

On the other hand, various mixtures exposed on the Belle Fourche, South Dakota, project were all found to be disintegrated at the end of eight months, with the exception of a 1 : 2 mortar specimen which was not affected. Concrete structures on this project have also been disintegrated by alkali. Other projects showed intermediate results. Analyses of samples from the Belle Fourche project show magnesium and sodium sulphates present in strong solution with the former predominating, and from the Sunnyside, Washington, project show sodium sulphate only, and in much lighter solution. For the present it may be concluded that in locations where alkali is present containing these salts, especial precautions must be taken to prevent its possible action, unless experience with structures previously built have shown no deleterious effect, as in the case of the Sunnyside project above cited.

The leaner mixtures of concrete are more easily disintegrated than the richer; also the more scientifically proportioned mixtures, that is, those having least voids for given proportions of cement and aggregate, give better results. This is a natural result, as the action results from seepage of water into or through the concrete which is retarded by the richer concrete.

With care in the selection of suitable aggregates, with proportioning to produce a rich dense mixture, and with proper methods of mixing and placing, it is possible to produce a dense impervious concrete that will withstand the alkali action under ordinary conditions, without the use of any special materials for waterproofing purposes. With fairly rich concrete an impervious skin of neat cement or rich mortar, such as is produced by working a flat spade between the concrete and steel or surfaced wood forms, will no doubt also have much effect in resisting the action of alkali.[1]

[1] Extract from report of U. S. Reclamation Service; *see also* Technologic Paper No. 44 of Bureau of Standards, by R. J. Wig and others, 1915.

CHAPTER X

EXPENDITURES, RECORDING AND CLASSIFYING

WAYS OF CLASSIFYING

It is necessary that the irrigation manager have for guidance a full statement of all expenditures, these being arranged in such groups or classes as to enable him to see at a glance where and for what purpose costs have been incurred. There is an infinite number of ways in which the expenditures may be classified, and whatever classification is adopted it is frequently necessary for particular purposes to have made special analyses or recomputation of expenditures. No two managers will be equally well satisfied with any one classification adopted, but each will desire to make certain modifications from time to time to give him a better grasp of the situation. There are, however, certain principles which are fairly well agreed upon as to lines of division of expenditures common to all irrigation systems.

The simplest form of classification is that of totaling separately the cost for labor and for materials, giving at the end of the month or year information as to the amount paid for each of these two principal items. In a large irrigation system, however, it is necessary to know the purposes for which these expenditures were made and it is often desirable to make comparison of cost between different systems. To do this other classifications must be adopted based upon certain large features. For example, all irrigation works include a distributing system, but may not have water storage; thus, to make useful comparisons, the expense of the distributing portion of each system should be separated from the expenses of storage so as to ascertain whether the cost of distribution in the one system is comparable with that in the other.

Following this line it has been found desirable to classify all expenditures for operation and maintenance under five general heads, as follows: (*a*) Development; (*b*) Carriage; (*c*) Distribution; (*d*) Drainage and flood protection; (*e*) Structure depreciation.

Development.—The operation and maintenance expenses which are included under the head of Development are those which pertain to the outlay made for obtaining or controlling the water or for getting possession of it, for example, by reservoirs which store the floods, by diversion dams taking it from the river, by pumping plants lifting it from the natural water courses or from wells or by other means of capturing the water and separating it from what may be called the wild or unregulated condition of nature. Included under this head may be the cost of dikes or drainage ditches for protecting the reservoirs and all of the subsidiary works which relate to the first or primary control of the water.

Carriage.—The expenditures which are made in transporting the water which has been captured by the development works are included under the head of Carriage, such, for example, as the cost of operating and maintaining the main-line canals or of the natural channels or water courses, which take the stored or pumped water from the point of original control or development to the head of the branch canals or laterals, which in turn distribute it to the fields. Certain canal systems have had large expenditures in the way of long and expensive canals around rocky or treacherous hill slopes before the water reaches the vicinity of the irrigated lands. The cost of operating and maintaining these expensive main-line canals for the carriage of the water from the reservoir or head works to the distribution system should obviously be considered separately in order to make useful comparisons of cost with those of canal systems which do not have the necessity for this large outlay.

Distribution.—The principal item of expense in connection with operation and maintenance is that of receiving and measuring water from the main canal into the branches and laterals and in turn delivering it to the farmers' laterals. Here there is not only the largest expense directly or indirectly, but the greatest economy may be enforced in the use of water and the greatest damage may result from lack of proper care and expenditure.

In cases of works, such as reservoirs or pumping plants for development of water and of main canals for its carriage, there are usually a relatively few obvious needs to be met. Extravagance or penuriousness in this work is easily noted, but in the distribution system with its infinite number of small details there is the widest range for use of judgment and for display of sound business methods by which to secure the greatest efficiency and economy in operating and maintaining the distribution system and also in producing the best results on the lands of the farmers.

Drainage and Flood Protection.—In some irrigation projects there are local problems of drainage or of protection from floods which necessitate large outlay. For example, where the irrigable lands are very nearly level or sandy in quality great amounts of water are frequently used and the whole area becomes water-logged —introducing the necessity, not only for greater economy in the use of water but also of large expenditures for keeping the top of the water table below the ground surface. In other cases where the irrigable lands are on the flood plain of a large stream, it is sometimes necessary to protect these against annual or occasional floods by a system of dikes, the cost of maintenance of which should obviously be separated from the other expenditures in considering comparative costs.

Depreciation.—There is still another item of expenditure which should be considered in rounding out the full presentation of operation and maintenance costs, and that is the depreciation which is taking place. Unless the amount of this depreciation is ascertained from time to time it is impossible to know whether the irrigation system is being maintained properly. The condition is similar to that of a merchant with a large stock of goods; unless he ascertains at the beginning of the year the amount and value of the goods on hand and again takes account of stock at the end of the year, he cannot find out whether he has actually made or lost money. His books may show an apparent gain, but his stock may have run down, or, on the other hand, his sales accounts may appear as though he had lost money, but in fact he has accumulated valuable goods for the next year.

The same condition exists under an irrigation system. One manager may keep all structures in good condition and spend considerable sums of money in having every detail in first-class working order, delivering water promptly and promoting the prosperity of the country, but at an apparently large cost. Thus he may gain a reputation for extravagance. The next man may rigidly cut down every item, gain a reputation for economy, but do this at the expense of the system and with occasional washouts or failures which may be attributed to natural causes.

Without a carefully made inventory or depreciation account, it impossible to show that the first manager with much larger apparent expenditures was really producing more economical results than the second with a smaller outlay. In other words, the inventory with proper items of depreciation is the keystone of the arch, or the connecting link, which sustains the whole structure of accounts and costkeeping. It is possible, of course, to depend upon general knowledge and on personal recollection; on smaller irrigation systems this is usually done. The depreciation on these is known in a general way and repairs are made only when absolutely necessary, to be charged usually not as an item of depreciation or of maintenance, but to capital account, thus serving to increase the apparent total cost of the system.

Operation and Maintenance Distinctions.—Throughout these primary or functional divisions of expenditure—development, carriage, distribution, protection and depreciation—run the two classes of work performed: operation and maintenance. That is to say, the expenditures following those for construction consist, first, of those which have to do with the operating of the reservoir or pumping works, and then those which are more closely connected with its maintenance or preservation. This division becomes more apparent in the items pertaining to distribution, where during the crop season most of the expenditures are for operation. Then after the crop season is ended in the northern lands the distribution system is cleaned and repaired and the principal expenses at that time are those for maintenance.

The maintenance charges are those arising from the wearing out or deterioration of the works used in the development and distribution of water. They include necessary repairs to the system and provision for prevention of destruction. Owing to the fact that the maintenance of the works is going on simultaneously with operation, it is not always easy to separate clearly those expenditures that should be classed under operation from those that should be classed under maintenance. In the main, however, there is little difficulty experienced in differentiating between the two clasess of charge. The operation charges are from their natures derived from expenditures in the handling of water and consist usually of salaries paid to, and supplies used by, the irrigation manager and his various office and field assistants, such as clerks, inspectors, hydrographers, watermasters, ditch-riders, and gate-tenders.

The maintenance charges result from expenditures for salaries and wages paid to, and supplies and materials used by, the irrigation manager and his various assistants and employees when engaged in repairing breaks, renewing structures and making improvements in the canal system after its construction. After the apparent completion of an irrigation system it is often necessary to line a canal, to provide additional riprap, to change the location of the canal slightly at some place, to use a different type of structure in some particular case, or to provide additional structures for the purpose of avoiding heavy maintenance charges. Such work of betterment is properly chargeable to maintenance unless it is desired to keep a separate account of the betterment items.

Account Numbers.—The splitting up under various heads of the expenditures made from time to time involves a large amount of labor. For example, a bill of materials may be received from a dealer, this bill including charges for lumber and hardware used partly in repairing the headworks and partly in the maintenance of the distribution system, together with items which are chargeable to operation of other features of the work. It is seen that the picking out of these involves not only full knowledge of conditions but a large amount of writing, especially if it is necessary to repeat the words "charged to maintenance of canal head" or "charged to cleaning lateral."

To avoid this excessive clerical labor a system of symbols or numbers is usually adopted, thus reducing the work to a minimum. For example, when the payroll or bill of materials is received, the superintendent or clerk who knows of the transaction takes the voucher, goes over it rapidly and assigns the different items or parts of items to corresponding features of the work, these being indicated by appropriate symbols. For example, 9–0 $17.00 indicates that on the particular payroll $17.00 is to be charged to the item of labor on concrete structure of main supply canal, etc. Thus on the back of the claim or voucher or on a slip attached to it, will be placed two vertical columns of figures, the first giving the distribution symbols, and the second the amounts, the total of which agrees with the total payment made.

By transferring these amounts according to the symbols given in the first column, the distribution can be quickly made and with the least amount of copying.

Various codes or systems of symbols are used. For example, a number followed by a dash will indicate the principal structure, as follows:

1–, Storage dam of masonry or concrete.

2–, Storage dam of earth.

3–, Diversion dam.

4–, Power plant operation and maintenance.

Another set of figures indicates the classification according to labor, materials, etc., as follows:

0, Salaries and wages, gate-tenders, watchmen and canal-riders.

1, Labor, men and teams.

2, Materials and supplies.

3, Travel and livery.

4, Depreciation on equipment (for office use only).

5, Camp maintenance (for office use only).

6, Superintendence (gravity), (for office use only).

7, Engineering (for office use only).

8. General expense (for office use only).

Thus, as given above, 1–0 will be the salaries or wages on account of the storage dam, or 1–2 materials and supplies chargeable to the same dam, and so on, the use of these symbols saving a large amount of time and bringing the distributed expenditures into systematic order.

The development of such a system is a matter of slow growth. There is usually a tendency to elaborate it to a point where such a large number of items are kept that the results may be more confusing than helpful. In all of these matters it is essential to have clearly in mind the object to be attained or the kind of information needed and to confine the clerical work to obtaining a relatively few facts rather than so many that the manager is more confused than aided in reaching conclusions.

The system of account numbers for operation and maintenance, including betterments, is similar to that adopted by many of the railroads. It is found that there will be required about 100 to 125 account numbers or even more if the system is complicated. Although such a system at first may appear to be unnecessarily elaborate, experience has shown that the clerical work is far easier than would be assumed from the description and that most of the operations which appear difficult are performed almost automatically, as the clerks handling these matters carry in their heads the account numbers and set them down far more quickly than they could write out any descriptive data.[1]

The time is approaching when all irrigation companies and similar public utility organizations will be required to keep accounts of this kind which can be compared with each other and from which conclusions can be reached regarding the relative efficiency and economy of the different systems of management.

Efficiency and Economy.—The object of any system of accounts or of recording and classifying expenditures is to secure the highest possible efficiency in the management consistent with economy in each detail. To bring

[1] *See* article by H. T. Cory in the *Proceedings of the American Society of Civil Engineers,* Nov., 1912, p. 1402.

about this result it is necessary, as before stated, to have accurate knowledge of the expenditures which have been made, and the liabilities incurred, rounding these out with an occasional physical valuation or by taking account of stock, by which it is possible to know whether the property itself has increased or decreased in value as a result of management.

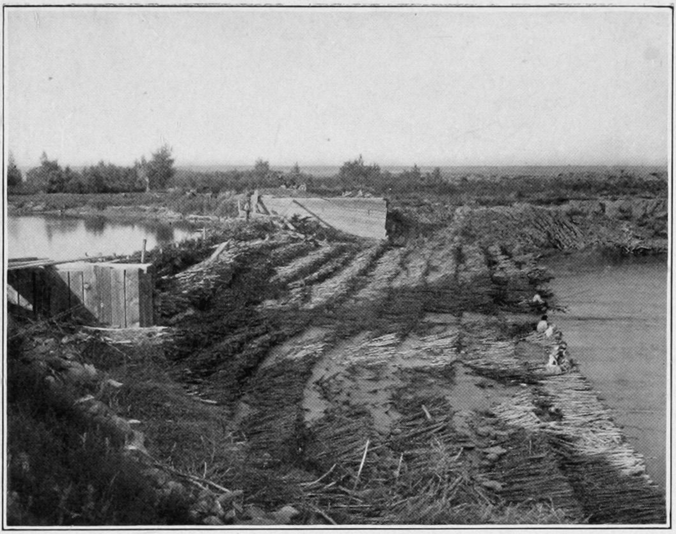
Attention has already been called to the fact that the classification of expenditures, or the mere statement of totals spent for various purposes, does not reveal the true conditions of efficiency and economy of operation and maintenance. It is possible for the works and the agricultural lands to deteriorate under a parsimonious management, and on the other hand, by using good judgment in expenditures, the property can be greatly increased in value and usefulness. The statement that so much more or less has been spent than in a preceding year means little or nothing as regards the effectiveness of the service, unless it is joined with a full knowledge as to what has been accomplished.

Costs are Large.—The costs of operating and maintaining a canal system are necessarily large. In the last ten years there has been a great change of opinion due to the accumulation of reliable data on this subject. At first it was assumed that these costs would be merely nominal, the opinion being based upon early conditions where a small group of farmers handled canals distributing water in continuous flow to large tracts and where the headgates, once set, were rarely changed, and where, as a result, from lack of care, a notable proportion of the irrigated lands either was not supplied with water or was ruined by an excess. In nearly all of these older systems from a quarter to a third of the best farms have thus been injured, and the small annual cost of operation and maintenance has been more than offset by the swamping of thousands of acres of land which otherwise might have been worth one hundred dollars or more per acre.

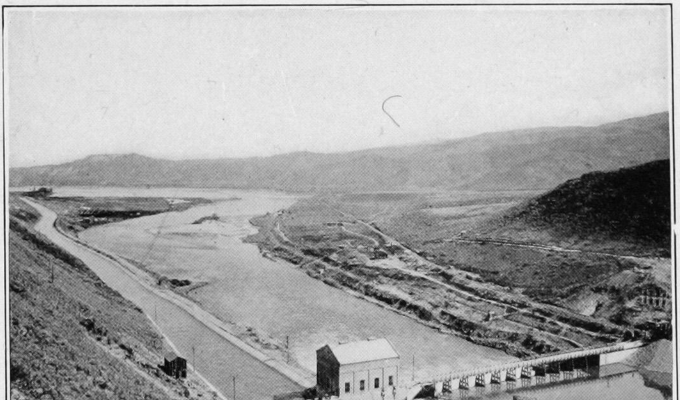
The fallacious ideas of cheap cost of operation and maintenance have been prolonged by the requirement of some of the state boards that the systems operating under the Carey Act should charge only a nominal rate, say thirty-five cents an acre, an amount which has been found to be only a third of the actual expense.

In any large system where water is economically handled and measured and where the works are maintained in good condition, the operation and maintenance cost cannot be kept down much below $1.50 or $2.00 per acre. Usually when such cheap costs prevail the maintenance and depreciation are not considered and the canal system is allowed to gradually deteriorate while a showing is made of small annual outlay.

The misinformation regarding the actual operation and maintenance costs has been increased by the efforts of interested parties to attract purchasers to irrigated lands by statements of the prevailing low charges. The average of operation and maintenance for the whole arid region of the United States is over one dollar per acre, but some of the larger private projects have agreed temporarily on prices as low as a third of this amount. The actual cost when properly entered may be, to the company, several times as great, but this fact is usually concealed and the water users later awake to the realization that they cannot properly operate and maintain the system at this cost after the works have passed into their control.



Old Diversion Dam in Milk River, Montana.
Temporary construction by community of farmers, with expensive brush and stone repairs.



Recent Concrete Dam, Boise River, Idaho.
Power plant and head of main canal, typical gravity diversion from river.

The erroneous assumption regarding small costs are the result of the lack of a good costkeeping system or of manipulation of an imperfect system, such that all extraordinary or large items are entered on the books, if at all, not as part of the regular operation and maintenance but are charged as new investment or added to the capital account. For example, following an unusually severe storm or cloudburst, the main dam or a flume or portion of a canal may be washed out, necessitating an expenditure of $5,000 for replacement. (See illustration.) This, in such a defective bookkeeping system as just noted, may be entered not as maintenance for that year but the money may be raised by special assessment and the account carried on the books as an added investment in the works.

In the case of the larger modern canals built by the Government or by large corporations, there are rarely found those conditions of ease or simplicity which prevailed on older canals which were gradually developed by coöperative work. In the case of the more modern systems, they have been built in more difficult locations and with an elaboration of detail, which is lacking in the earlier works. There has not been practicable the development from the outset of that spirit of coöperation among the settlers which tends to keep down costs. On the contrary, large numbers of men from various parts of the country and with different experience, have been attracted by advertising and brought together, being located largely by chance on lands under an elaborate irrigation system and one which requires far more skill in its maintenance than the earlier more simple works.

In the early stages of settlement under these newer systems the time of the water user is more largely needed in cultivating his field. He cannot be depended upon to respond to immediate calls of the watermaster to make repairs or to clean out the distributing system, and thus keep down the expense, but, on the contrary, he expects that this will be done for him by the central organization. The water user finds it easier to pay for having this operation and maintenance work done than to take his own time to do it. This means that the total costs as charged on the books are far higher in these modern systems than in the case of the older ones where the labor or the time of the individual water users in making these repairs or in cleaning out the ditches was not charged or considered in making up the estimate of total expenditure. In the older system, the majority of the farmers accepted, as a matter of course, the fact that they must clean out some miles of lateral in order to get water to their land and considered this, if at all, as part of the ordinary farming expense rather than of the operating of the canal.

It thus happens that in making comparison of the alleged costs of some of the older simpler systems, the manager of the more modern canal may be discouraged by the fact that he finds it impossible to maintain his system properly at the small costs which are quoted to him. He should bear in mind that the conditions are frequently not comparable; that the cost of operation and maintenance as given frequently does not include those items such as he must insert on his books in order to have full account of the time and money spent on the system. In other words, in order to have a proper comparison, the manager of the up-to-date system must call for an analysis of these alleged low costs and inquire into the fact as to whether they include all the costs, especially the overhead charges and learn whether the canal system with which comparison is made has been deteriorating as a whole during this period of supposedly low cost of maintenance.

As an example of alleged low cost of operation and maintenance of one of the older canals of Utah, may be cited a case where the manager in good faith stated that the cost was only 48 cents per acre. A more careful analysis of the figures given by his books, however, showed that by taking the actual acreage irrigated in successive years, the costs for 1912 were as follows:

	Cents per Acre
General expenses and supervision	16
Operating	17
Maintenance	67

making a total of $1 per acre on the main canal alone of the operation and maintenance. To this should be added 42 cents per acre for the work put by the farmers upon the sublateral system, which was not included in the expense of the canal itself. In the succeeding year, 1913, the figures per acre irrigated were for:

General expenses and supervision	.18
Operating	.16
Maintenance, including some replacement	$1.18

a total for the main canal of $1.52, to which should be added the estimated cost of the lateral system of 42 cents, making a total of $1.94.

Instances of this kind could be multiplied where the man in general charge of the work, taking only a part of the figures, thoroughly believes that he is operating the works as a very low cost, whereas, if he had an analysis made in the same manner as that of one of the larger Government canals, he would be surprised to find that his costs instead of being less are sometimes greater than in the case of the Government works.

The results of these simple and relatively inexpensive methods of operating and maintaining are frequently shown in the relatively small crop production compared to the large amount of water applied. This is accompanied by a rapid spread in the area of lands which are injured or destroyed by seepage (see page 128); such destruction being due in part, at least, to the wasteful manner in which water has been allowed to be distributed to the fields.

As an inference from what has been above stated, it is obviously a mistake to attempt to keep the costs of operating and maintaining below the amount needed for the greatest economy of water and the consequent larger production of crops. In other words, 50 cents an acre saved in operation and maintenance may be at the expense of several dollars an acre in crop production. While the irrigation manager should strive at all times to reduce expenses and secure the highest economy, this should not be done at the expense of efficiency in the management or at the expense of ultimate rapid deterioration of the irrigation system or of the lands served with the water.

Costs, Public and Private.—The relative cost of operating and maintaining works under the control of the Government or of a large corporation affords a field for interesting study and should yield valuable results. It is difficult to make a comparison upon a uniform basis as the managers of large private works have not as yet generally accepted any one system of handling their accounts. They are gradually tending to adopt the methods of bookkeeping and costkeeping followed on the larger Government canals. It is frequently necessary for the accountant to go somewhat deeply into details to interpret the statements as issued by the various companies.

The comparison also of cost on an acreage basis introduces the very serious complication as to what acreage is to be considered, whether that actually irrigated and cropped or the acreage for which water was available.

In the case of the works built by the Government an attempt is being made to divide the costs on a uniform basis, so as to secure accurate figures. In comparing these with the statements prepared by private companies, it is at once apparent that the cost of the Government works is large. This is due in part to the requirements of law and regulations with regard to numerous details but the difference is more apparent than real as it arises largely from the fact that the private company usually does not include all of the items. If a statement could be prepared by the same man acting under the same rules for both private and public works, it would probably be shown that much of the so-called inexpensive private management was really more costly than appreciated by the owners.

Work Orders.—To insure efficient and economic conduct of the work, it is necessary that before any expenditures are incurred, there be prepared an estimate of the probable cost and comparison of the total of these estimates with the available funds, considering at the same time all outstanding liabilities.

On a small irrigation system it is relatively easy for the manager to carry many of these things in his head and, trusting to memory, avoid the trouble of keeping detailed records. Unfortunately, however, after a few years, when the management changes, there is little or nothing of record as regards past expenditures. Thus contradictory ideas develop as to how much was or was not spent on certain items of the work. The tendency is to assume that in the past certain operations were performed at less cost than at present.

It is desirable and even necessary for the safe conduct of the business that a simple but effective system be followed of preparing preliminary estimates and issuing "work orders" based on these estimates and covering all of the larger as well as smaller items. These work orders consist simply of the estimates, reduced to writing, put in some conventional form and properly approved by the responsible men, thus forming the basis of authority for the proposed expenditure.

The work orders for operation and maintenance for the ensuing season are best prepared by consulting the records of cost of the preceding year and increasing or decreasing certain of the items in accordance with changing conditions.

The value of simple but accurate records of past expenditures classified under various heads is appreciated when it is time to prepare the work orders for future operation and maintenance. At that time comparison naturally follows and the whole question of the economics of the system is brought into review. The work orders are prepared following the classification previously prescribed for the costkeeper. These give the list of items, as indicated by the proper symbols, and opposite these the proposed expenditures for the ensuing month or season. At the top or bottom of the sheet should be placed the amount available for expenditure, with existing or probable liabilities, and the total of the work orders should be deducted from the net balance available.

From time to time as conditions develop, it is necessary to increase or decrease certain of these items and the system adopted should be such as to enable this to be done readily, but at the same time should necessitate careful record of the fact that certain items of the estimates have been increased or diminished. If a rigid routine is not insisted upon, the man in direct charge will occasionally be tempted gradually to exceed the estimate without definitely calling attention to the matter. The work-order system to be effective should be such that every increase over the approved amount must be noted by promptly placing on record the amendment of the original work order so that the fact of this increase may be clearly made known. The greatest danger of any system of this kind arises from neglect of this detail. It is of the highest importance, that everyone connected with the work be required to record the reasons and secure formal authority for every notable increase of expenditure, as in this way alone can the responsible management keep properly informed.

The work orders should be so prepared as to bring together all of the facts, not only concerning the probable cost but also permit later insertion of the actual cost in terms of completed structures. It has been found, for example, as shown by Mr. H. T. Cory, that concrete structures cost from $30 to $35 a yard, including such items as backfill, overhead charges, etc. Such general statements are more useful in considering work of this kind than the more detailed figures as to the cost of the concrete itself, say, $12 to $15 per yard, and of the cost of reinforcement, forms, etc., to be added.

At the end of each month reports should be made of the percentage of completion under each work order and the results obtained, so that the manager may know how all important jobs are progressing and their approximate cost, and have always at hand the larger items essential for executive judgment.

Damages.—Probable expenditures for damages must be fully considered, in any estimates of future expenditures, as part of the cost of operation and maintenance. The damage claims may be quite large and may arise from neglect of detail in the maintenance of the system or from unforeseen and unpreventable causes—for example, cloudbursts, or disturbances such as the experience of the oldest inhabitant has not before encountered.

The claims made for damages are usually far in excess of the actual injury or of the amount for which settlement may ultimately be made, but the amount paid is dependent largely upon the skill with which the claims are handled on behalf of the management and the precedents which have been established in this connection.

The projects which are being owned, operated, and maintained by the Government are to a certain extent free from damage claims as the Government cannot be sued directly upon matters of this kind; although suit has occasionally been attempted against its agents.

It is impossible for any large work conducting water through hundreds of miles of canals and laterals to be so controlled that at some point or another damage to private property is not involved. The most common occurrence is the break by which the water damages a field of grain or alfalfa. Such breaks may take place as the result of a sudden cloudburst or of a combination of circumstances—for example, the occurrence of a shower during which the farmers wish to close their headgates. If these are not locked, the shutting down of many will at once check the flow and the excess water must escape somewhere. Even with a full system of wasteways, a condition may arise where the water will work injury to the individual.

When the works built by the Government are turned over to private parties, or in the case of systems owned and operated by large corporations, there are frequently considerable claims for damages. These may be divided into several classes, as follows:

1. Those for actual injury, due to breaking of the canal.

2. Failure to deliver water at the proper time or in proper quantity, with resulting failure of crops.

3. Injury to animals falling into the canal.

The laws and decisions in the various states regarding damages vary widely and as yet there is no uniformity in treatment of these matters. In most states, however, the Court will not hold an irrigation company legally liable unless there has been a showing of improper construction or negligence on the part of the company or its employees. It is stated that the courts of Colorado, in one case, have held the owner responsible for all damages that have resulted or flowed out of a disturbance of natural conditions, due to the building of a reservoir.

It is advisable to have certain well-considered rules regarding compensation for injuries to the lands or crops, so that there may be full understanding of these matters in advance, and while such rules might not have legal standing, yet their moral effect would doubtless be good in preventing disputes over minor matters or claims, or especially for failure to deliver water at some stated time.

Betterment Charges.—One of the largest items of discrepancy in comparing the management cost of private and public works is that which attaches to the so-called "betterments." It is probable that some time will elapse before a general agreement can be reached as to what is to be included as betterments and the place to be assigned in the costkeeping system. In the Government projects betterments are considered as closely joined to maintenance and are entered usually under a subheading of the maintenance items. To illustrate this point, the case of a wooden structure as previously noted may be considered. In building the canal it is usually desirable from economy to erect a considerable number of wooden structures. After the canal has been in use for eight or ten years, it will usually be found that a wooden structure, though frequently repaired, must be entirely renewed. At such times it is usually decided that the new structure should be stronger or larger than first planned. When rebuilt on the same lines, it is usual to charge the cost of rebuilding to maintenance, but if it is built larger and better than the old, the difference or increased cost resulting from this enlargement or from substitution of concrete or steel may more properly be considered as an item of betterment of the system.

Depreciation.—Nearly all of the structures connected with an irrigation system become less secure or less valuable with age. This is conspicuously noticeable in the case of wooden gates or bridges which must be replaced at the end of eight or ten years, on which the depreciation is correspondingly from about ten to twelve per cent. Tools, wagons, etc., wear out in the course of a few years and horses become old: the depreciation on the tools being as high as twenty to thirty per cent.; on horses and wagons somewhat less. At the other extreme, are the great dams built for all time, in which a life of at least one hundred years is assumed. The reservoirs behind these dams, however, may gradually fill with silt and their capacity be reduced so that it is safe to assume a depreciation of say two per cent. on the reservoir created by the dam.

In order to ascertain the true cost of operation and maintenance it is obviously necessary to carry on the books a suitable depreciation to cover the wear and tear of equipment and of the structures which are gradually becoming less valuable, although still in service. There is a wide difference in practice in this regard and a headgate which is on the verge of going out, but which may last for another season, is in one sense just as serviceable as it was when new. The common practice is to disregard the fact that this headgate must be renewed until the time when it is actually taken out and then charge the cost of its replacement or betterment as one of the items of ordinary maintenance. In this way, the cost of maintenance in some one year may be double or treble that of previous years or may be so great as to require a special levy or assessment for renewals, which are not considered as maintenance items.

In order to obtain comparable results of cost of various irrigation systems, it is obviously necessary that there should be some uniform practice in regard to this matter of depreciation, as its presence or absence vitally affects the totals. The true cost, for example, of operation, should take into account the wearing out of the tools or equipment. The cost of maintenance of the structures should be accompanied by a clear statement as to the extent to which depreciation of these structures has been entered on the books.

The determination of the amount of depreciation of each structure or class of structures must be left with the irrigation manager and his assistants in the field, who are acquainted with the peculiar conditions and the length of life of similar structures under like conditions. In all considerations of cost and expenditures this matter of depreciation must be kept prominently in view. Neglect to do so results in fallacious assumptions concerning the economy of operation and unfair comparisons between the management of various men. For example, one man seeking to show economical operation may be tempted to omit or cut down the depreciation item and show a corresponding gain, while another man, really a more effective manager, may conscientiously show the depreciation and apparently have larger expenditures, although actually keeping the work in better condition.

Many of the worst blunders in financing irrigation systems have arisen from failure to take into consideration all of these items of depreciation and treat them fairly, so that there is no one matter which must be given more thoughtful consideration than this of the gradual depreciation of structures and the allowances to be made for them.

It is an open question as to how the item of depreciation may be handled; whether to set aside each year an amount as a sinking fund, or whether to let the depreciation item accumulate in the nature of a probable liability to be met at some future time by special assessment. The latter is the plan usually adopted, as the financial condition rarely warrants any company accumulating a sinking fund.

Sinking Fund.—Closely connected with the method of handling depreciation is that of the creation of a sinking fund to take care of this depreciation. Theoretically, the mangement should set aside each year enough money to offset the decay of wooden structures, for example, so that at the end of the tenth year, there would be available adequate funds for rebuilding these structures, thus the cost of maintenance will be distributed uniformly. In a community, however, where money is worth ten or twelve per cent., or even more, or where it is almost impossible for the farmer to borrow money on any terms, it is obviously unwise to accumulate a reserve sinking fund to meet this depreciation. On the other hand, it is far more economical to treat these renewals as matters of emergency to be paid for by special assessment when the work must be done.

CHAPTER XI

RECEIPTS AND VALUES

REPAYMENT OF BUILDING COST

In the management of any old, well-established irrigation system, the matter of repayment of cost of the system and of collection of building charges has presumably been settled, but, as a matter of fact, on most of the large canals in the United States, whether built by public or private capital, there still remains a large amount to be paid on the original investment. The irrigation manager is, therefore, more or less directly concerned in seeing that this investment is returned and that payments are made annually or at periodical intervals; also that collection of claims for cost or building are properly followed up.

When most of these larger works were planned, it was assumed that payment could be made in ten years or less, Nearly all of the first estimates of revenues or earnings have been based on this assumption. Experience has shown, however, that under usual circumstances this payment in ten years has been impossible of accomplishment and that, although there is a considerable percentage of the newcomers on any project who can make payment within ten years or less, there is also a very large body of irrigators who find it impossible to obtain needed money to level and develop their farms, support their families, and make the annual payments required in the original contract. It has, therefore, been necessary in most cases to extend the time, usually on an interest-paying basis. In the case of the works built by the Government, however, no interest has been charged for such extension from ten years to twenty years.

There is required a high order of business ability in order to properly handle this matter of collections. In the case of corporations the questions of extending or adjusting the time of payment can be met largely on the individual basis, through the use of knowledge on the part of the manager as to the financial ability of each of the irrigators who had contracted to make the required payments.

In the case of the Government projects, however, the exercise of individual judgment is more restricted, as these matters are necessarily governed by law and regulations which cannot discriminate between individuals to the degree that is possible in the dealings had by corporations or private companies. With such persons somewhat rigid rules must be followed and in order that a relatively few deserving individuals may not be oppressed, liberal terms have been granted to all. For this reason, the precedents established by the Government in this respect cannot always be followed in connection with corporate efforts.

As regards the ability of the pioneer or early settler on a new project to make payments of the building cost or for water rights, it may be said that there is general agreement as to the fact that such a man entering upon the work should have at least from \$1,500 to \$2,000 to establish himself properly upon an irrigated farm of from forty to eighty acres. Even larger sums are needed to prepare the ground and put it in good productive condition, but the average success has been made probably with about this amount of money available. Of course, there are instances where a man has come upon a piece of raw land and with nothing except the labor of his hands and use of his brains has succeeded in making a living and ultimately has secured a valuable farm and home for his family.

These instances, however, may be considered as exceptional and as tending to prove the rule that a certain amount of capital is required in order to make a successful start. On the other hand, men have come upon the new lands with amounts as high as $10,000 and have promptly proceeded to lose all of their capital, not making a success until down to " bed rock " and without an available dollar but with experience which ultimately enabled them to make a new start and achieve a telling victory.

For example, an inexperienced entryman came to one of the projects with about $8,000 and tempted by the statements of the real-estate dealers, purchased 160 acres of unimproved irrigated land, paying down nearly $5,000 on account. He discovered that his remaining capital was not sufficient to put the land in productive condition and found himself with a tract of land so large that he could neither utilize it to advantage nor could he dispose of the excess over what he could handle at the price which he had agreed to pay for it. After he had sacrificed about 80 acres, he was then able with his own labor to develop the greater part of the 80 acres remaining. Had he confined his purchase and efforts to 40 acres at the outset he would have been able to put this in early productive condition by using the fund then available and to keep up his payments on the 40 acres—a condition impossible of accomplishment on 160 acres.

The ideal condition of making payments of building cost is to require at the outset a fairly good installment on this cost, say, at least one-tenth. Many private companies require that newcomers shall pay down from twenty to twenty-five per cent. of the cost of the water and lands, in case they are selling the land with the water. It is believed that at least one-tenth payment should be made in advance to insure good faith and to give the settler such reasonable interest in the land that he will not throw up his purchase when the first difficulties are encountered. If he has not made any considerable payments down in advance, he is apt to be easily discouraged and move to some other locality, as there is nothing in particular to induce him to remain and try to overcome unexpected difficulties.

After this first considerable payment, those required for the second and third years should be small, being conditioned, however, upon the investment by the irrigator of an equivalent amount at least in the cultivation and improvement of the place. In other words, if conditions are made such that the newcomer will develop his farm and thus improve the security, he should not be required to make payment on account of the water for two or three years. There should be, however, reasonably exacting conditions, which will necessitate maintaining or building up the fertility of the soil to its highest productivity, and putting permanent improvements upon the ground in the way of fences and buildings, as well as providing necessary farm animals. By thus deferring the early payments of building cost, the settler should be able, at the expiration of two or three years, to begin to make substantial payments. These should then increase in amount until about the tenth year, when they should reach the maximum which the soil is capable of producing.

PAYMENT OF OPERATION AND MAINTENANCE COSTS

The operation and maintenance costs on any irrigation system continue as long as the system is used. They require annual expenditures which must be met either in advance or at the end of the irrigation season. In case these estimated costs are not paid in advance, it then becomes necessary for the management of the system either to use reserve funds for meeting the wages and material bills, or, as is usually the case, to borrow an amount of money adequate to meet immediate needs and pay interest upon this until the dues are collected from the individual water users at the middle or end of the irrigation season.

Unlike the building charges, these operation and maintenance costs cannot be indefinitely deferred on the ground that they are a permanent investment in adding to the value of certain lands, but they must be kept up year by year. It is possible that at the outset they may be allowed to accumulate in part to be met by payments to be distributed over subsequent years, but this condition evidently cannot be long continued.

When a project is first initiated, and when all of the lands are not yet under irrigation, the question of the proper distribution of the operation and maintenance charge is serious. It is obviously impossible to assess the full cost of operating and maintaining the system provided for, say, 50,000 acres upon only a part of these lands. During this first year only 5,000 acres out of the 50,000 may be actually cropped, and in the second year 10,000 acres, and so on. Under these conditions, the operation and maintenance charge must be handled in one of the following ways:

(*a*) Accumulated against the lands which are not taking water and be made payable when these are sold or water is applied for them, or

(*b*) These early costs must be added to the building charge, or possibly,

(*c*) Carried as a deferred charge to be distributed over the subsequent years. The problem is a difficult one and any of the three ways above suggested is open to objection.

Assuming, however, that the project is already completed and the lands utilized to an extent such that the majority of them are in cultivation, then the annual cost of operation and maintenance can presumably be collected from these lands. The question to be determined, if not already settled, is whether such collection should be made in advance or distributed through the year. There are certain advantages of collecting this amount in advance at the beginning of each spring, notably as affecting the water economy on the tract and in keeping down the excessive application of water if the operation and maintenance charge is made proportional to the amount of water which is delivered to the lands.

For example, when a water user comes to the office to ask for a certain amount of water to be delivered to his land, if at that time he is required to make payment of the amount of water demanded, it is almost invariably the case that he will conclude that he can get along with a less amount of water than the quantity he would order if the amount were simply charged on his bill to be paid at the end of the year. This condition has been found to exist on irrigation projects and that with this less amount of water, the irrigator as a rule can produce better crops than by a more lavish use, also he is less likely to fill up the ground water and raise the water plane to a point where he will injure the fields of his neighbors. For this reason, the requirement, as stated before, of payment in advance for water ordered tends not only to promote economy in the use of water but a better cultivation of the fields and a larger production.

One provision which has been found to be of advantage is to add to the estimated cost of operation and maintenance when collected at the end of the year an additional amount of about five per cent. to cover cost of collection. If the water user makes prompt payment, before the bill is sent to him, say on the first day of December, and thus avoids the clerical and other expense of collection, a rebate of five per cent. can then be made on the operation and maintenance charge. If, however, he does not make a prompt payment and a bill must be sent to him, then at the end of the thirty days a penalty of one per cent. is added for each month during which he has delayed to make payment, thus following the precedent established in many counties in the collection of taxes. Such course of procedure is a source of economy to the management and gives certain advantages to the man who makes prompt payment.

CARRYING OR RENTAL CHARGE

Prior to the completion of a large irrigation system and the formal opening of it with declaration of cost and of all of the other related conditions, it has been found advisable to permit water to be used on a rental basis or a charge for carrying it to the land. When the first governmental irrigation projects were partly completed under the terms of the Reclamation Act, it was held that this could not be done, but as experience was acquired, the law was more liberally interpreted and authority was granted to operate some of the canals which had been purchased in connection with the construction and enlargement of such systems, water being furnished to these canals on an annual charge prior to the time when regular payments of the building costs should begin. This has been found advantageous, not only to the water user, but to the management itself, as it permits the lands to be watered before the system is fully completed and the canals and distributing systems to be thoroughly tested and the earthwork to become seasoned.

There are two classes of cases which have been treated in this manner. The first class is where the resident farmers are relatively few in number, and where it would be impossible for them to pay the full expense of operation and maintenance. For example, it is usual that the farmers are not in a compact body, but are scattered about, so that laterals built to supply ten farms may be called upon the first year or two for only two or three of these farms. It is impossible for these few men during the first year or two to carry the entire cost of maintaining the system and operating it to these isolated spots.

Under these conditions a nominal carrying charge has been fixed and any excess of cost above that returned by payment of this has been charged to the building account, inasmuch as it is believed to be necessary to make these expenditures in getting the system in good working order.

The second class of conditions is where the major portion of the land is under irrigation and where the area irrigated bears such a large ratio to the total irrigable that the total cost of operation and maintenance can be borne properly by the farmers who are enjoying the use of the water, inasmuch as they secure the entire direct benefit of the operation and maintenance and at a rate which is reasonable and frequently less than that of other projects. The effort is made in the second class of cases to charge and collect the entire cost of operation and maintenance, but without an allowance for interest or depreciation.

Charges Proportional to Water Delivered.—The annual charges, whether for the carrying of water to the irrigators of the projects not yet completed or formally opened, or for operation and maintenance on those which have been completed, should be based upon measurement of the amount of water delivered at each farm. It is alleged in opposition to this that the cost of operation will be increased, but experience has shown that this small additional cost is made up many times over, not only by direct economy in use of water, but also, as above stated, on page 196 by larger crop production and reduction of losses to the community due to swamping of the lands.

The same principles apply as in the sale of any other commodity. The experience of mankind has shown that wherever a flat rate is charged, there is waste and indirect losses, as, for example, in selling natural gas or of electric light and power under pioneer conditions. There is no more reason for disposing of water without measurement than there is for permitting coal or groceries to be delivered without measurement or record of the amount taken by each individual.

Where the lands of a project are fairly uniform in character, the problem of payment on a measured basis is relatively easy. It is possible to set a somewhat arbitrary but fair minimum quantity of water, for example, two acre-feet per acre to be delivered to the farmer at an annual charge of say $1, this amount to be paid whether the whole quantity of two acre-feet per acre is used or not. Each water user is then entitled to this amount, i.e., his two acre-feet for each acre of irrigated acre contingent on beneficial use. When this is used he can then order as much more water as he desires, making payment, preferably in advance, for additional water at a rate of 50 cents per acre-foot, delivered at his land. This rate of 50 cents per acre-foot is continued until he has had a complete acre-foot per acre for his irrigable area. For the first two acre-feet he has paid at the rate of $1 per acre-foot and for the third acre-foot at 50 cents. When, however, he desires an additional amount above the three acre-feet per acre, the rate should be increased to say 60 cents per acre-foot until he has used an amount equivalent to four acre-feet per acre when the rate should be increased to say 75 cents per acre-foot, and so on, increasing the rate per acre-foot as more and more water is used.

This increased rate per acre-foot is justified because of the fact of the increased cost in operating the project; also by the reduction in amount of land irrigated when using an excessive amount of water on any given area, and the frequent destruction to neighbor's property by such excessive use. As above stated, the requirement of payment in advance when ordering this additional amount of water is found helpful in that an irrigator will order less water if he must pay for it in advance.

Sandy Lands.—This system of requiring a minimum payment for a certain amount of water, say $1 for two acre-feet per irrigable acre, becomes somewhat difficult or complicated where a project consists of lands varying widely in their physical properties. Where in one location the lands are extremely sandy and in another the area consists largely of heavy clay, it may appear, for example, that on the sandy land it is necessary to have several times as much water as on the clay lands. Various efforts have been made to set different standards for the minimum amount of water to be delivered under these circumstances, i.e., that for $1 per irrigable acre, there will be delivered to the sandy lands three acre-feet, and to the clay lands only one acre-foot.

Experience has shown, however, that it is not as necessary to classify the lands on this arbitrary basis as was at first inferred, and as the lands become better developed and the owners acquainted with their physical character, it frequently happens that the sandy lands can be successfully irrigated with a far less amount of water than was previously assumed. Thus the problem in actual practice is perhaps less difficult than might be anticipated from theoretical consideration.

There are, however, conditions where the land is so sandy that in spite of all efforts, a considerable amount of water is required in excess of that needed for adjacent heavier lands. In such cases, the suggestion has been made that an organization of the water users appoint a small committee to act together with a representative of the manager, to go over these sandy tracts and to arrive at some arbitrary rule or understanding by which the owners of these sandy lands may receive the water at a less rate per acre-foot than the owners of other lands. In other words, if in the opinion of experienced men the average lands of the project require only two acre-feet and these sandy areas require four acre-feet to produce profitable crops, the rule may be made that on such lands an amount of four acre-feet may be furnished at the same rate as the two acre-feet on the other lands. This implies, of course, that any loss due to reduced cost per acre-foot for this particular land must be made up by distributing the amount pro rata to all of the other lands of the district.

While such a scheme as above proposed is simple in conception, it is found in practice to be extremely difficult of application, because there is no sharp line of demarcation between the very sandy lands and those less sandy or relatively heavy and requiring less water. The quantity of water needed is also a matter largely of skill and individual experience, so that on one piece of sandy land, it may appear that a farmer has raised a successful crop with half the amount of water which his neighbor claims to be absolutely essential.

COLLECTION METHODS

The methods of making collections of operation and maintenance dues are as a rule those which are pursued by the business houses or corporations in similar debts. It is important that each water user be notified promptly at the end of the month of the amount of water delivered (see p. 114) and be kept informed, so that if there is any complaint or misunderstanding as to the quantity, this can be taken up while the matter is fresh in mind. At the end of the season, say, during November, general notices should be issued to the effect that the water users who make prompt payment at the office before bills are sent out, may be permitted to take advantage of a certain cash discount over the charges imposed on the others, in recognition of the saving in clerical work and the corresponding expenditure in making out bills.

On the first of December, the estimated cost of operation and maintenance should be ascertained and to this an amount of approximately five per cent. should be added to cover cost of collection. If, as before stated, the payments are promptly made before the bills are sent out then this amount of five per cent. should be deducted for prompt payment.

As soon as possible after the first of January, or by January fifteenth, active efforts should be made to secure collection through sending out circular letters or mailing notices, and on the first of February and on the first day of each succeeding month a penalty of one per cent. should be added.

It is essential for the success of any project that prompt payment be had of the cost of operating and maintenance, otherwise the management must borrow the money to carry on the work and be put to unnecessary expense in all of its clerical and related operations.

Accumulation of Charges.—A serious problem arises in connection with the lands for which water has been provided and which are not being irrigated and consequently in which operation and maintenance charges are not being paid. It is obvious that these lands which are not in use should make payments for the maintenance of the system which has been built for their use. The fact that the lands are not cultivated should not relieve them from payment, as the cost of operating and maintaining is nearly as great whether these lands take water or not. In other words, the charges should be accumulated against them.

The serious objection to such accumulation arises, however, in the fact that when these lands are finally to be put to use, there is a large bill for back charges to be paid. It is sometimes extremely difficult for the newcomer to pay these off in order to begin the work of cultivation. At that time he has greatest need for his money and is deterred from going to the expense of properly leveling the ground and cultivation, if he must first meet old charges which have been accumulated during several years. To be able to meet them, they must be distributed over a term of years.

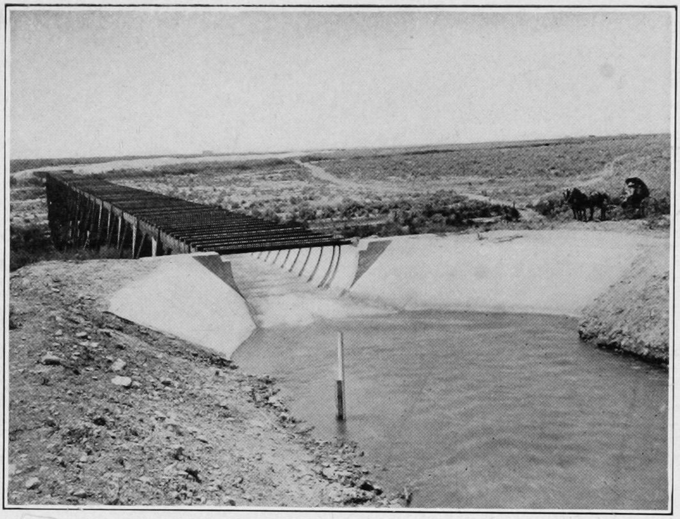
On the one hand, the threat of accumulation of the charges is assumed to act as a stimulus to the owner of the land to put it into cultivation at an early date. If he does not do this, then the accumulation soon becomes a burden, such that he cannot dispose of the land to others or utilize it himself to advantage.

Time of Payment.—Experience has shown that throughout the United States the proper time to insist upon the payment of any debt by a farmer is when he is selling his crop, and that this time is usually late in the fall or during the winter season. At that period only does he usually have funds to meet his bills. It has become the custom at that season to collect taxes. Merchants then find that they are able to collect in whole or part the debts which are due to them. It is wise to fall in with the general custom, to send out bills at about the time the crops are being gathered and press for payment continually with other claimants at the time when crops are being sold.

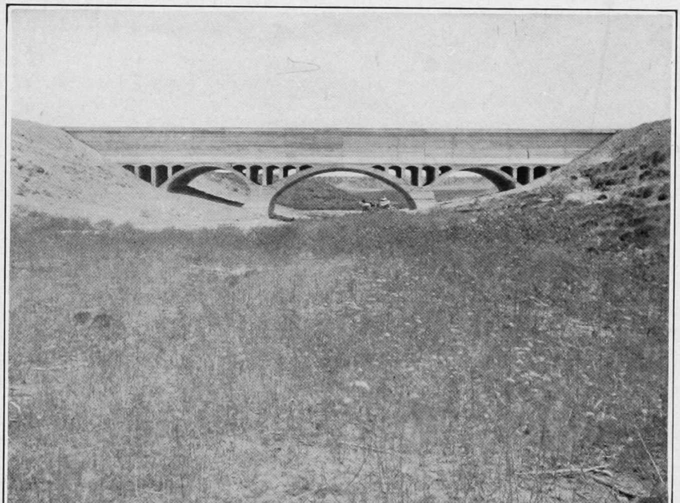
It has been urged, however, that if pressure is applied too early in the winter, the farmer will be forced to sell his crops in competition with his neighbors and at a loss, while if he can carry some of them, particularly his hay and potatoes, till later in the winter, he can probably obtain a larger price. While this is occasionally the case, there is an element of risk about it; instances are numerous where the prices did not rise in the late winter or early spring, but on the contrary declined, and the farmer who held his crops was finally forced to dispose of them at a lower price than he could have obtained earlier in the year. In any event, it is seen that the attempt to make collection in the spring is usually not a success because at that time the farmer has paid such of his debts as he must; he is fortunate if he has enough capital left to procure the necessary seed and to make arrangements for getting his land in best condition for cultivation.

VALUATION

The ability to secure repayment of the original cost of the works and of the expenditures for operation and maintenance measures the value of an irrigation system. It is the principal business of the manager to obtain these returns and to see to it that by the exercise of every possible precaution the canals under his charge



Metal Flume for Conveying Water across Depression on Boise Project, Idaho.



Concrete Flume on Interestate Canal across Spring Canyon, Eastern Wyoming are rendered profitable. It does not necessarily follow that these profits take the form of immediate money returns, for in the cases where the landowners and irrigators are themselves the proprietors of the system or where it is owned by the general public, the returns may be in the form of increased crop production, and while the investment in the canal itself may be apparently lost, the values created by it will compensate for the outlay for construction. Under such conditions the manager for his own protection at least should collect statistics or have available such information regarding the lands and properties benefited by the canal as will demonstrate the fact that it is bringing about an increase in productivity.

It is highly important that each year or at other regular intervals the true value of each irrigation system be ascertained. This is needed to round out and complete the knowledge on the part of the owners as to where they stand with reference to the investment. The fact that in some cases the Government or public may own the canal adds rather than detracts from the importance of such estimate or inventory. The valuation of railroads and other public utilities is now being undertaken, and the underlying principles are being widely discussed. Little, however, has been done on the valuation of irrigation systems. In a few cases the Government has had occasion to purchase such systems, mainly bankrupt, and which were needed as parts of a larger or more comprehensive scheme.

In the case of irrigation canals or similar works purchased by the Government, consideration was given to each of various methods of ascertaining the value. Of these methods, three were prominent:

First, the original cost;

Second, the value based upon earning power;

Third, cost of reproduction.

The owners in each case made strenuous plea for payment of the original cost, but it was quickly seen that much of the original cost consisted of expenditures for promotion or for works such as dams and headgates which had been swept out of existence by floods. In one case, for example, the purely legitimate expenditures had been over $1,000,000, but it was obvious that any such sum would be out of the question, and the amount agreed upon was about one-fourth of this.

It was equally impracticable to fix any sum based upon earning power, as most canals under consideration were costing for maintenance far more than the annual receipts. If this had been used as a basis it would have had a negative value and the owners should have been glad to pay something to any one who would relieve them of the ownership and consequently of the duty of supplying water.

The third plan was finally adopted, namely, to pay the reproduction value of such portions of the irrigating system as could be utilized in the new work. While this may be open to objections in many cases, yet the irrigation manager in considering the value of the property and its earning power may safely estimate on the cost of reproduction, writing off to profit and loss the expenditures for works which have been put out of use.

There is need of the adoption of some well-considered rules for valuation of irrigation property, so that comparison may be made between the irrigation works conducted under various conditions. When this is done, the managers, as well as the people interested in service from the canal, can begin to discuss intelligently the efficiency and economy of service rendered and the necessity or fairness of the accounts charged for delivering water.

CHAPTER XII

THE IRRIGATOR AND HIS ASSOCIATIONS

Irrigators' Success.—The success of the irrigators is at the bottom of the success of the irrigation project. Unless the average man on the land is able to make not merely a living, but also to accumulate gradually a competence for his old age, it is obvious that the efforts made in the reclamation of the land cannot be considered as successful. It is not only necessary that he be reasonably prosperous in a financial way, but more than this, that he be contented, have a feeling that he is making progress and that he is as well off, if not better, than his fellowmen in other occupations. Success is to be measured not merely by the question of money returns, but even more than that by contentment or by the mental attitude of the man and his family toward the farm and home. Even though it appears that a living has been made, accompanied by gradually increasing property value, yet, if, at the same time, the children are discontented and are longing to leave the farm, it follows that the work can hardly be claimed to have been a complete success.

From the manager's standpoint also it is essential that there be a continual appreciation of the opportunities offered and willingness on the part of the majority of irrigators to coöperate with him and with each other, in ways such as are now recognized as being essential for the best development of an agricultural community. Coöperation is founded primarily upon mutual confidence and upon an expectation of realizing beneficial results. The conditions on an irrigation project are not like those in a factory, or in ordinary industrial organizations, where the manager can displace the unsuccessful workman and substitute a man better equipped for the particular operation. On the contrary, the individual farmers as landowners are fixed in their places and if not successful cannot be immediately replaced by better equipped men. It takes time and a considerable amount of actual hardship to the unfit individual and his family before he realizes that he is unsuited to the task and before he is willing to sell out to some man who is better qualified as an irrigator. Changes take place on every project, but these are slow, far slower than is the accumulation of difficulties and expense due to the presence of a number of unsuccessful farmers. In other words, the irrigator is a relatively fixed factor and the irrigation system deteriorates more rapidly and the expense of operation and maintenance accumulates at a faster rate than the population adjusts itself to the existing conditions.

Pioneering.—The development of the arid West is accompanied by many of the difficulties and discomforts which are inseparable from pioneering. It is unfortunate that in recent years many of the persons who have been attracted to the reclaimed area have come with an exaggerated idea of the ease of cultivating and producing crops. They have been drawn by stories of success which, to say the least, have not been accompanied by the disagreeable side, and have been allured from their old homes by the hope of being free from many of its discomforts or disadvantages, not realizing that each locality has its own peculiar difficulties which must be overcome and that nowhere, and especially in a new country, can a living be had without considerable hard work and self-denial.

The newcomer to an irrigated area, especially one where the works have been recently constructed or are only partly completed, finds that everything is yet to be done. The land must be leveled in order that water may flow freely over the surface, the small distributing ditches must be provided, and more than this, after the ground has been prepared for irrigation, it must usually be supplied with some lacking elements of plant food, especially with such as are usually rare in the arid region and which are grouped under the name of humus. While many of the arid soils have certain elements of richness, yet nearly all of them require some building up in order to bring them to a state of high productivity. More than this, continued efforts must be made to maintain and increase this ability to produce crops. There should be a continual study of crop rotation and the selection of the crops which are not only best adapted for the soil but which will find a ready market.

The pioneer also has to build a house for his family and a shelter for his stock, fence the land, and make other improvements, so that while the cost of water may be forty to fifty dollars per acre, or even more, he finds it necessary to invest an equivalent or even larger amount in getting the farm into shape for maximum production. If he has been so unfortunate as to acquire an area larger than he can properly handle, he is apt to become discouraged or attempt to spread his efforts over too large an extent of land to secure the best results.

Land Poverty.—The attempt of the newcomer to obtain and hold a large area of irrigated land has been more destructive to his success than any other one cause of failure. There is an overwhelming desire on the part of the pioneer to acquire and hold as large an area of good land as he can obtain. There is a vast area to be had; there is a golden opportunity and the newcomer is strongly tempted to buy or agree to purchase or to enter upon more land than he really believes can be put to immediate and profitable use by his own efforts. But he reasons that as the country is developed, there will be a rapid rise in values, as has happened in the past and he can then sell some of this extra land to advantage; or he has a growing family and while the land is on the market he should get enough for all possible future contingencies.

Here is where he makes his fatal mistake. His anticipation of rapid increase in prices is not always fulfilled, but on the contrary, after the lands have been disposed of and the first rush to the newly irrigated area is over, there is usually a set-back and the prices which have been inflated drop to more normal condition. This occurs largely because of the fact that the newcomers begin to appreciate the difficulties of putting the land in good condition and find that far more capital is required than anticipated. Many of them endeavor at about the same time to unload some of the lands which they obtained at " boom " rates and which, unfortunately for them, cannot be sold except at a lower rate.

Acting under the impulses above described, however, many a man has attempted to obtain and hold, say, 160 acres, while possessing strength and capital adequate only for about 40 acres. Usually the inexperienced irrigator attempts enthusiastically to spread his energies over the entire tract. He does not handle any part of it in the proper manner to produce the best crops; hence, the average crop production is small, the costs of water, of operating and maintaining the canal system and also the taxes on this large area quickly eat up his accumulated capital and discourage him.

In contrast to the above-noted condition, if the new farmer had confined the same efforts to say 40 acres instead of 160 acres, in a few years he might have reached a condition where he could then acquire larger areas and select these on the basis of the experience already had. The 40-acre man, at the end of five or six years, is apt to be in a position to expand his holdings and to acquire lands from his less successful neighbors, namely, the man who started in with 160 acres of irrigated land. Instead of the 160-acre tract increasing in value, it is usual that the price which is offered after the first few years of effort is as low if not lower than the mortgage which usually rests upon lands acquired in this way.

These conditions are thus brought forcibly to the attention of the manager, who must listen to many pitiable tales where men have loaded themselves with more land than they can handle, who are struggling to hold this land, not realizing that they have already lost their equity in it and that every year of continued effort is simply reducing the chances of success and is a year lost in their lives. These cases appeal strongly to the manager because he must see to it that the collections are made partly on building charge and certainly for the operation and maintenance. His sympathies are appealed to in every direction, although his memory and reasoning power show him that the unfortunate conditions which have resulted have been due to mistaken judgment in attempting to hold more land, rather than to any defect in the land itself or the system of irrigation.

New Projects.—The new projects and the new settlers offer to the manager problems quite distinct from those which are presented on the older projects where knowledge has been obtained by practical experience in handling the soil, and in marketing crops. On these new projects, everything is yet to be discovered; for success managers are required of perhaps more ability and experience than those who are carrying on the work in older and better established localities. There is an innumerable number of precedents to be set which, if laid down with full knowledge of the conditions which will follow, may, on the one hand, result in continued, prosperous growth; on the other hand habits may be easily established which may require years of effort to overcome. For example, in the matter of distributing the water, at the outset, when water is plentiful and only a small proportion of the land has been cultivated, the manager in his desire to be obliging may permit every man to take all of the water he desires, whenever he sees fit. Under this condition the settlers quickly acquire the habit of demanding the water without reference to the needs of their neighbors or to the capacity of the canal. In a few months, they get into the attitude of believing that it is their right to be served in this way and feel that they are being defrauded unless the manager is able to meet their convenience.

In the meantime, however, with increased area under cultivation accompanied by larger demands for water, the manager soon finds it necessary to establish a regular schedule of rotation and also discovers that the liberal use of water is threatening to swamp some of the lands.

He thus is in a position of trying to bring it out a systematic delivery of the water and its limitation to the amount actually needed by the lands, while under the difficulty of correcting the bad habit so quickly acquired. Under these conditions he is greatly embarrassed because the needs of the entire system must necessarily interfere with individual license in taking water.

The Farmer's Home.—The success of agriculture under irrigation, notably in the hotter parts of the arid region, is closely connected with the securing of a suitable home for the family. This is especially the case in southern Arizona and adjacent parts of the West, where during the long heat of the summer, the comfort and even the health of the newcomer is largely dependent upon the adoption of some form of house designed for relief from extremes during these hot days. The natives in these regions have worked out the problem, as many of them came originally from parts of Spain where through centuries of experience there had been developed the thick-walled house with inner rooms, dark and cool during the long hot summer days. These people have learned to retire at noon to these inner chambers and sleep during the extreme heat of noontide, thus being fresh for labor in the cool of the evening and again in the early morning.

In contrast to this the newcomers from more humid and cooler regions construct houses of thin boards sometimes even with black iron or paper roofs, which become so intensely hot during the day that it is impossible to stay in them. Consequently to obtain needed rest they sleep late in the cool of the morning and at a time when their labor would be of most value to the farm. They unthinkingly try to adhere to the hours of labor suitable to colder climates.

Under these conditions the families cannot remain on the farms with comfort, at least while the extreme heat of summer continues and at the crop period when labor is most needed. It is therefore one of the needs of the Southwest to build adobe or similar thick-walled houses in which the family can find a cool retreat during the extreme heat of the day and be ready to work during the cooler hours. In one of these board houses the temperature may run up to 110° while in a neighboring thickwalled adobe in the inner recesses the temperature has been as low as 80°. A person is able to sleep with comfort under the latter conditions whereas in the more common type of house, it is impossible to obtain any rest.

ORGANIZATIONS

Effective coöperation is essential to the success of a community of irrigators, even more than with any other body of farmers. One of the first duties of a manager on a new project is to see to it, as far as lies within his power, that organizations of the irrigators are formed for the promotion of mutual interests. In such matters, however, it is wise for him to keep in the background, while at the same time doing everything possible to stimulate others to take an active part and to work for the common good.

The organizations which are primarily needed are those which will induce the individual irrigators to consider the best methods of cultivating the soil, the best crops to be raised, and the ways of handling these crops to get them to the markets—also of purchasing needed supplies or securing credit. It has been frequently said that the pioneer farmer, acting individually, pays the highest price for the commodities needed by him—including credit—and sells in the lowest market.

This condition is due to the fact that acting individually the farmer is to a certain extent in competition with his neighbors. When he goes to the bank to borrow money, he has only his own personal credit behind the loan, as it often happens that his farm is not available as an asset in borrowing money. In taking his produce to the local market, he is usually offering it to a group of men who are acting more or less in concert and who have an understanding as to the rates at which they will purchase the crops of the individual producers. In other older-settled countries, this condition has long been known and carefully studied, with the result that the individuals have found that they can combine for mutual protection and benefit, coöperating in the form of various volunteer organizations through which, instead of paying the highest price for seed or for plows, they purchase these wholesale and obtain through competition among the sellers the most reasonable rates.

In the same way, when offering their produce for sale, instead of bringing it to a market which is practically fixed by a group of men, the producers themselves, uniting in the handling of the crops of a community, are able to secure competition from buyers which enables them to obtain the highest price. This is true also of buying the use of money. By united effort and by putting the unlimited credit of a group of individuals behind the need, money can be had from a wider range of markets than that offered locally and at conditions and on terms which are more favorable than those which could be enjoyed by the individual acting alone.

The deplorable results of lack of coöperation are notable in the localities where as yet the irrigators have not become accustomed to work together and where individualism has been carried to an extreme. Under these conditions, the project manager acting through or with the more progressive men of the community can aid in improving conditions by diffusing information regarding the results of coöperation elsewhere and by assisting, in a minor capacity always, in the formation of committees in discussing the lines upon which progress may be made.

In earlier years there was not the present difficulty of securing organization among the water users in a given district as the then existing conditions forced upon the pioneers a mutual aid far greater than is required under existing situations. The very life of these early communities demanded such mutual assistance. The people settling along a stream in an arid region were bound together by ties of friendship or former neighborhood association. The common difficulties and dangers brought about a high degree of mutual protection and the communities in which effective coöperation did not exist in some form were soon wiped out. The small irrigation canals were thus built and operated by coöperative effort, success being dependent upon each man's doing his share.

Later, when the irrigation works were constructed by outside capital or by the Government and settlers were attracted from all parts of the earth, there was not possible at the outset the same degree of community life. The result has been a more complete individualism, which, beneficial in some localities, has been injurious in others. Under the older systems it was usual for each small group of irrigators to appoint its own watermaster, who saw to it that water was turned to the fields of the various owners. Under the larger corporate system, however, the farmers on an irrigation lateral are not neighbors in the full sense of the term. They do not have the same interest in each other's success and it has rarely been possible for them to associate in distributing water fairly among themselves. It may take a generation for them to learn those lessons of mutual respect and forbearance in water distribution which the older pioneers were forced to adopt in face of failure.

From this it results that in the large irrigation systems built by private capital or by the Government, the method of distribution of water must be quite different from that practiced by the coöperative irrigators. The water must be taken to each man's farm because if left to be distributed among a small group there is always complaint that the man at the end of the lateral or the weaker member of the community does not get his share. It is necessary to have some one strong central authority to whom this man can appeal as against the propensities of his neighbors to take his share of the water.

Water Users' Associations.—Among the most important organizations which should be perfected on any new project is that of all of the water users, in the form of a corporation under general state law, or of an irrigation district created under special statutes. These organizations should ultimately maintain and control the works and see to the fair distribution of the water. The sooner they are started, the better for all concerned, as it is inevitable that some mistakes must be made at first and the earlier these are made on a small scale, the quicker will successful results ensue.

The original water users' associations on reclamation projects built by the Government were formed for the purpose of insuring to the United States the returns on the investment in irrigation works which are of benefit to the private lands included in those projects. The formation of such associations was not encouraged in cases where the greater portion of the land was in public ownership, and was taken up under the terms of the Reclamation Act.

The first association was on the Salt River project, Arizona, and the forms of articles of incorporation, by-laws and of the contract then adopted served as a model for the other projects. As experience has been acquired, these original contracts have been modified from time to time until now they are greatly simplified from their original form. The Government officials followed the precedent thus established, until it became apparent that the associations were not fully carrying out their original object; then an effort was made to accomplish the desired results by substituting a trust deed instead of a water users' association.

The objections to an association during the early stages of a project are based largely on the fact that it is an expensive and cumbersome organization without any immediate duties. As a result, few of the busy men on the project attend the meetings and affairs are left to a minority of relatively inexperienced persons. Having nothing particular to do and with the large machinery of the association at their command, the energies of those in charge are often devoted to irrelevant discussion rather than to constructive effort. The tendency has been for similar organizations to enter upon debates and to fall into the control of a small clique of men eager to take up new theories of finance, but slow to assist in a constructive program.

One argument in favor of these water users' associations in addition to that of securing the debt to the Government, is that they should be representative of all of the people and active in promoting the general welfare. This is a condition which has been hoped for, but not always realized. As stated above, the successful farmer is too busy to take time to go to town for the frequent meetings of the association. On the other hand, the less active man, who is frequently found at the village store, is constant in attendance.

Much time and effort are required to develop in the minds of the officers or directors of these new water users' association the fact that they must be guided by a broad public spirit such as will lead them to view the operations of the association with reference to the greatest good to the entire community. A more altruistic spirit must be cultivated in order to enable these associations to carry on successfully the work for which they are organized.

With added experience and with progress of time, there usually comes a larger conception of the needs and opportunities of the community as a whole, and there is every reason to believe that by the time the lands on the larger projects are well tilled a class of men will be developed who can and will devote their time unselfishly to the interests of the public. In this as in all matters of democratic government, the chief difficulty is to get the right man in the right place, and to give him sufficient authority to enable him to carry out in a broad way the interests of all rather than of any special group of individuals.

Coöperative Organizations.—In addition to the water users' association on each project, it is usually desirable to promote other organizations for special purposes, such as the marketing of potatoes and of alfalfa, or the obtaining of credit and improving the conditions on the farm. At first, it was thought that the water users' association might properly perform all of these functions, but experience is showing that as a rule, it is better to organize separate societies rather than attempt to have all of these various functions performed through one office or set of men. For example, the potato growers on the project can probably handle their business better through their own organization, uniting with potato growers in other parts of the state. In the same way the men producing apples, organizing an association of men composed of specialists in this line, are better qualified to select their own agents and direct this particular activity than is a larger group of people representing a variety of interests. In the same way, the dairy association finds that its business can best be conducted through an organization independent of the water users as a whole.

There is also a certain advantage in this specialization of the organizations in that it distributes the offices and responsibilities and arouses a more general interest than is the case when one organization, with a certain set of officers, is attempting to go into so many different lines of business, success in any one of which demands men of highly specialized training.

The water users' association might very properly provide a building or headquarters for the agents of the various organizations and places in which to hold the meetings, but the actual transaction of the business itself as above stated, can usually be done best by organization more or less independent of the water users' association, but closely connected with similar lines of activity on adjacent projects.

As before stated, however, it is part of the business of a manager of any project to keep in touch with all such movements and to do what he can individually to stimulate and assist them, without at the same time offering assistance in such a way as to paralyze the efforts or reduce the activities of men whose personal devotion to the cause in hand is so essential to success.

FARM MANAGEMENT

There is no one line of agriculture in which carefully planned, scientific farm management is more productive of large results than in irrigation, where the farmer enjoying sunshine during the greater part of the daytime throughout the year, can control the amount of water and thus have available those elements which go to insure crop production, namely, sunshine and moisture. The business of farm management is being now more generally recognized as a science and textbooks and reports have been prepared on the subject showing the elementary features as well as the detailed practice in various lines of effort.[1]

The United States Department of Agriculture in particular has issued among other bulletins one entitled, "What is Farm Management," by W. J. Spillman, agriculturist in charge of the Office of Farm Management. In this, farming as a business is treated in concise form.

[1] Notably "Farm Management," by G. T. Warren, Rural Text Book Series, 1913.

It discusses, for example, the relative desirability of farming and other lines of business, the selection of the farm, the organization, equipment, and the farm operation. In this connection, the irrigation manager is chiefly interested in farm administration and in such questions as the system of laying out the work, the hiring of labor, the work schedule, or distribution of effort, the care and upkeep of the equipment, the bookkeeping which shows how these profit and losses are made, the purchasing of supplies, marketing of products, and in general the efficiency of the management by the owner or tenant.

The average farmer born on the farm has acquired certain ideas from his immediate surroundings, usually those of the eastern humid country. He has unconsciously acquired definite practices, and is apt to think that he knows all about farming and farm management. It is a revelation to him to discover that farming is a business —and like all other businesses is capable of indefinite improvement in methods and results—and that there are certain well-established rules which lead to success as in the case of any other enterprise. More than this, he is often surprised to learn that farming really requires a larger business sense and experience than most other industries. It is far more complicated and the farmer, to obtain the largest results, must not be merely a producer of raw material, such as alfalfa and potatoes, but he must to a certain extent work these up into finished products as in the case of any other manufacturer. The successful farmer must continually study his markets, be prepared to meet the shifting demands and handle his goods either by coöperation with his neighbors or in other ways to obtain the highest prices. All of this opens out wide vistas of possibility and of indefinite progress along the lines leading toward success.

It is very difficult and perhaps impossible to convince the old farmers of some of these facts, but with the younger men and the larger children attending school, it is possible to produce an impression. There grows in their mind the appreciation of the fact that they and their parents do not know everything there is to be known about farming, marketing of products, etc., but that there is still a field to be explored and one which brings not merely personal reward in the way of better prices, but an absorbing study of the possibilities and one tending to relieve the monotony of the daily grind.

When once it is fully appreciated that through carefully considered farm management, it is possible to get out of the daily rut and not merely improve conditions but secure personal pleasure or gratification in daily improvement, however slight, there is aroused that spirit of progress and emulation which is so important to growth in any business.

The success of the irrigation farmer is largely dependent upon his knowledge from day to day of what his crops are costing and what are their true values. It is well known that the ordinary farmer may continue year after year to raise and sell crops at financial loss, thus gradually eating up his capital or getting into debt without knowing really what is happening. In the highly specialized industry of intensive farming under irrigation with diversified crop production and working up of by-products through the feeding of animals, the owner of the farm must know where his profits lie and where his losses occur. This cannot be done by mere general knowledge or by inference any more than it can be in any other business.

Yearly Business Inventory.—The importance of keeping records, already touched upon, can hardly be overemphasized. It is as vital for success to the farmer as to the storekeeper or manufacturer. These records should be rounded out by a yearly business inventory. Even though the farmer keeps little cash on hand, yet he should know what has become of money or credit he has received. In the usual course of events, the farmer sells some product and immediately buys a new implement or another animal or repairs his buildings. During the course of the year he may receive and pay out considerable sums of money, although at any one time or at the end of the year he has practically no cash on hand. The annual returns may seem to have consisted only of a fair living for himself and family; if he looks only to cash on hand, he may be disappointed. The balancing of his books, however, with a carefully made inventory, may show a good profit. On the other hand, even though considerable money is in the bank, this may be only an off-set to the depreciation or a result of reduction of his net investment.

A yearly inventory should comprise a list, with values attached, of everything used in the farm business, including land, buildings, livestock, machinery and tools —also the produce on hand for feed or sale and a list of all bills receivable as well as payable. A comparison of the inventory of the preceding year to which has been added the receipts since that time, with the outgo deducted and the remainder checked up against the inventory, brings out the true conditions needed for the farmer's guidance and encouragement.

The present is the age of specialization. Irrigation farming is perhaps the most highly specialized of agricultural industries. The difference between the farmer of to-day and his father and grandfather is that he now produces principally for the market, while a generation or more ago he produced mainly for home consumption. The successful farmer of to-day is not only a producer, but also a manufacturer of raw material, and a merchant. He must thoroughly understand not only the production side of the business, but also the merchanting. There are thus three matters of fundamental importance.

First, the farmer must have a thorough system of records, showing him how he stands with reference to the farm and the cost of production.

Second, he must practice the methods of working up the raw products into the most compact and salable form, disposing of his forage "in the hide of a steer or the skin of a hog."

Third, he must understand enough of market conditions to be able to dispose of his product at the right time, or, through coöperation with his neighbors, under right conditions to get the highest prices.

The agricultural colleges and farm advisors are accomplishing excellent results in bringing forward this side of the farmer's work and are teaching both by direct instruction and by correspondence the elements of farm accounting, costkeeping, and business organization. The irrigation manager should keep in touch with these and aid in diffusing a better knowledge and appreciation of such efforts.

Farm Laborers.—The question of the farm laborer is one of the most difficult in the irrigation problem. The size of the irrigated farm is more largely dictated by the difficulty of securing adequate farm help than by any other one factor. It is not possible with the relatively small profits of irrigated farming to pay large wages, and for the amount which can be paid for the laborer, there is expected from him a range of experience and ability and an amount of hard work, which is rarely to be found in any other occupation.

It is frequently assumed that the farm laborer is unskilled; to a certain extent this is true, but, as a matter of fact, the effective farm laborer has a large amount of information and experience in his trade, such as is not to be had in the ordinary unskilled labor in the cities. In the latter it is possible to pick up and utilize scores of men for industrial purposes, organizing them in gangs and training them in a few hours to work together in simple matters of handling a shovel, or piling up bricks, the same operations being performed hour after hour and day after day under the eyes of a foreman. In the case of a farm laborer, however, this is entirely different. There must be a large amount of experience previously had in handling animals and farm tools, and while to the boys who have been born and brought up on an American farm it seems as though the work was extremely simple, yet to the farmer wholly unaccustomed to American ways, and without experience with animals and machinery, the work becomes almost impossible. It is extremely difficult and unsatisfactory to attempt to teach a grown man some of the matters which are so easily picked up in childhood and which are vital to the success of a farmer.

This fact is rarely appreciated and it is assumed that any one of the great hordes of men out of work in the cities could be utilized to advantage in the field. Experience shows that such men when brought into the country, not only will not stay there but are wholly unfitted to country life and to meeting the hourly emergencies which arise on the farm. They have a lack of what the Yankees term " gumption," and must be told each thing tc do and how to meet the simple occurrences of everyday life.

DISILLUSION

The majority of newcomers to an irrigated district usually come with exaggerated ideas as to the comforts or advantages which they will find when once they have settled on the land. This condition must be recognized and suitable allowance made for the resulting reactions and the mental disturbances or storms, just as must be done for natural phenomenon, whether of wind or flood. In cases when men come on a project a few at a time, the inevitable disillusionment of these few has no general effect and the tactful manager is usually able to take each individual case and bring about a better appreciation of the opportunities. But, where large groups of newcomers arrive in a body, then the condition becomes more serious.

The reason for such disappointment is obvious. It arises from the fact that most of the people who have come have been attracted by advertisements or by statements which necessarily have dwelt upon the good features, even exaggerating these and the benefits to be derived by changing from the old homes. It has not always been possible to give proper weight to the discomfort and disadvantages of the new locations, because these are not as apparent to the man who has lived on an irrigated farm as they are to the man from the humid region. It is almost impossible to picture the condition of mind of the person who comes from the humid east and for the first time is exposed to the hot dry sun, the dust and other surroundings inseparable from the arid West.

Conditions which are familiar to the older inhabitants and to which the newcomer himself gives no heed at a later date, are often oppressive or almost unendurable during the first few months. He finds also, as in all similar enterprises, that he must unlearn many things which he has considered as fixed. He must acquire entirely new habits and attitudes towards his work. All of these things bring about a mental wrench and predispose him to find fault with conditions in general, the soil, the climate, and particularly the representative of the organization under which he is working, namely, the manager of the project. This manager can be most easily reached and is inseparably connected in the minds of the newcomer with the conditions which led him to come to the new home.

The patience and wisdom of the manager is thus continually taxed, especially at the outset when there are large numbers of men unused to irrigation. At such times it is necessary for him to exercise the skill of a diplomat with the experience of a business man.

He must bear in mind that this discontent is temporary in character and that with lapse of time the regrets diminish; in fact, the persons who at the outset are most disappointed in the contrast in the conditions which they left in their old homes—or with the picture which they had in mind of the place they were coming to—are the very persons who later become most enthusiastic and forget and even deny that they ever had any illusions on the subject. Nevertheless, at the time, these disappointments are very real and as in the case of homesickness, to which they are closely allied, must be treated with an understanding of the symptoms of the disease.

It may be a source of consolation to the manager to know that the conditions on his project are not unique and that all men in similar positions are subject to similar trials. Sometimes, the manager under a Government project thinks that he in particular is signaled out for trouble, but, as a matter of fact, the relations between the management and the water users on private projects are, as a rule, even more strained than those on a Government project. There may be less publicity about the matter, as it is of less public interest, but nevertheless the effective manager of a privately owned project, like the settler, has no bed of roses.

Investigation of Complaints.—The complaints which habitually come to the irrigation manager may be grouped into several heads, some of which are the mere normal expressions arising from homesickness or discontent, and others from causes which may be ameliorated in part. The most important complaints are those which have to do with the integrity and high moral standard of the employees whose business brings them into daily contact with the irrigators. Any suspicion of unfairness or of "graft" should immediately be followed up and given the most complete inquiry. On the other hand, the ordinary complaints of failure to receive water at the time set or in the order agreed upon, which are usually due to some misunderstanding of the wishes of the irrigator or of the established necessary regulations, may be considered as less serious, though possibly indicating lack of thoroughness on the part of the individual immediately concerned. All of these should be looked into, but with especial emphasis as above stated upon those matters which reach to the moral soundness of the organization.

Complaints are the valuable warnings or danger signals to the manager, and while the details of investigation may be properly assigned to trustworthy assistants, the manager himself must know at all times what is the true nature of these complaints and while not giving too much of his own time to the matter, be sure that prompt attention is being given to each statement. As far as possible he should investigate on the ground and with the individual concerned rather than make the matter one of public or semi-public conference, as he is more apt to arrive at the true situation through personal interviews than through statements made in public meetings where there may be the tendency "to talk to the galleries."

Every reasonable facility should be afforded to the individual water users to make known their grievances, and they should be made to feel that they are welcome at all times to present the facts, especially in writing, where these can be carefully studied. Every farmer or resident on each project should have ready access to the manager and receive prompt attention, even if his case appears trivial, proper safeguards, however, being provided against misuse of time by habitual fault-finders.

It is desirable to have frequent informal discussions with the principal officers of the water users' associations, at which project matters may be freely discussed. Although such procedure sometimes takes much valuable time, yet it is productive of good. The opportunity of free speech is usually appreciated, and in most cases certain troubles, which otherwise might assume large dimensions, when discussed, are dropped.

EDUCATION

During the part of the year when the manager and his assistants are less busy with the details of operation and maintenance, it is desirable to have a series of meetings or farmers' institutes at the various schoolhouses or convenient points in each neighborhood to talk over the problems of farm management and of improving the general conditions of a locality. Such discussions when constructive in character, are helpful not only to the individual but even more in building up a community spirit.

In organizing these winter meetings, the initiation can be secured or coöperation usually had with the field agents and employees of the United States Department of Agriculture and the state agricultural college. The manager can be most effective in encouraging the holding of these meetings and in giving advice with reference to the various persons who are best adapted to take part in the work.

There have grown up also a series of correspondence schools, established by the agricultural colleges and other institutions, by means of which the irrigator, especially during the winter months when he is less busy, is able to acquire considerable information and advice concerning the methods of irrigation, cultivation, marketing of crops and other conditions. These correspondence schools are especially valuable to the younger watermasters or canal-riders, in giving them general information and in better preparing them for the work of the succeeding year, enabling them in time to advance along the lines to the highest positions in the management of canals.

The most important educational feature, however, is that of the county adviser or experienced agriculturist working with the state agricultural college. He visits the farms during the irrigation season, and becomes personally acquainted with the problems of the individual farmers. The systematic extension of these agricultural college short courses and instructions in the field is doing much to make more effective the work of the irrigation manager. Also with the gradual spread of agricultural schools throughout the irrigated tracts, there comes a higher appreciation of the value of water, the opportunity of raising crops, and of the necessity of following a certain prescribed system in the operation and management of the work.

Posters.—One of the interesting features of recent work of the state experiment stations has been the issue of posters giving in condensed form some of the elements for success. These are sufficiently short and explicit to enable a busy man to grasp the ideas in a few minutes, and being put in places frequented by farmers, serve as a topic of conversation or attract the attention of a man waiting for some purpose. In this way the irrigators, especially men who have newly come to the country, are greatly benefited. As indicating the character of the advice given in these posters, the following quotations are made from one issued by the Montana Agricultural Experiment Station in 1915.

IRRIGATION SUGGESTIONS

Irrigation water intelligently used is one of the most valuable resources in the State. Improperly applied, it is very harmful. Exercise care in its use and irrigate the greatest possible area of land with the water available. Avoid the difficulties arising from overirrigation.

Save the Rainfall.—Early spring cultivation of plowed fields and harrowing or disking immediately behind the plow in the case of spring plowing holds the water for use by the crop. Do not let the fields dry out before spring planting. Potatoes, corn, sugar beets, etc., should be cultivated as soon as they come up and kept cultivated till time to irrigate.

Keep the Soil Fertile.—Fertile soil produces a crop with much less water than does a poor soil. Grow soil-improving crops like clover, alfalfa, peas, etc., in a systematic rotation on each field. Use all the barnyard manure available.

Prepare for Irrigation.—Level the fields before seeding. Clean out all head ditches and main laterals immediately after spring seeding. Put in field laterals and dams as soon as the grain is a few inches high. Use a level in putting in laterals and do not get more than 1 inch fall to the rod. Survey laterals every spring and do not follow old lines exactly as this tends to make a depression in the field and the level of the field changes somewhat with each season's cultivation.

Irrigate at the Proper Time.—Grain crops ought to be irrigated very soon after the crop shades the ground. In most parts of Montana one irrigation is sufficient for grain crops if the spring moisture is conserved by tillage.

Alfalfa and clover ought to be irrigated either sometime before cutting so the ground will be dry enough to permit the hay to cure, or immediately after the crop is removed.

Sugar beets should be irrigated in furrows between the rows, care being taken not to flood the beets. If cultivation has been properly kept up irrigation may be delayed until in July. Hold off the water as long as possible without causing the beets to suffer. Two irrigations should make the crop. After irrigation cultivate as long as there is passage through the beets.

Do not Overirrigate.—Land is irrigated to increase the crops.

This is most effectively done when the soil is moistened to a reasonable depth. When this has been accomplished further irrigation is harmful. One-half foot in depth over the land is usually ample for grain crops, and 1 foot for hay crops. Where the water supply is limited, as compared with the land available, much more crop will be produced by the moderate use of water over a large area of land than by adding an excessive amount of water to a smaller area.

Keep Down the Alkali and Prevent Water-logging of the Soil.—Leaky ditches and the excessive use of water over the land are the chief causes of these evils. Repair the leaky places and do not use too much water or flood the land too long. Prompt spring cultivation and careful irrigation will avoid many of the alkali troubles.

Kill the Weeds.—It takes as much water to grow weeds as it does the same weight of valuable crops. Proper crop rotation and thorough cultivation will hold the weeds in check.

Measure the Water.—Measure the water used. The seed is measured, and a proper amount of water is just as essential. By installing simple, inexpensive weirs, any farmer may measure water accurately.

[1] From *Reclamation Record,* Aug., 1915.

CHAPTER XIII

METHODS OF APPLYING WATER

THE manager of an irrigation system must have had experience not only in practical application of water to the fields but also should be broadly informed concerning the different methods so that he may advise his assistants and they in turn be prepared to exchange ideas with the farmers in the fields. While it is not often practicable or advisable for him to attempt directly to teach the irrigators better methods, yet he should be competent to exert an indirect influence towards securing greater economy and efficiency in the use of water.

VARIATION IN PRACTICE

In the actual application of water to the soil there is great variety in the methods employed, these being dependent largely upon the abundance of water, the skill of the irrigator, and the climatic conditions. For example, where the climate is warm, and water is scarce and consequently very valuable, as in southern California, it becomes possible because of the high cost of land and the value of the crops, to incur large expense in procuring water and to pipe it to the field and bring it underground to the plants. In this way, there results an elaborate water-supply system of conduits and pipes comparable to that of a city or town and accompanied by the highest economy in the use of water.

The cost of this complete distribution by means of pipes is prohibitive in the greater part of the arid West, where the value of the crops does not justify such large expenditure in bringing water to the fields. The essential conditions for the greater part of the irrigable area is to obtain and conduct the water in the cheapest possible manner by gravity. In order to secure economy of cost, it is necessary that the canals be built mainly in earth and as a consequence, there must be large loss in carrying the water. Thus great economy in the transportation of water for irrigation is not possible under usual conditions. In the same way it is not practicable for the average farmer to secure ideal economy in the distribution of the water to his fields, such as would be essential in the warmer climates where water is more expensive.

The various methods of distributing water to the fields after it has been delivered to the farm may be classified in accordance with what is now known of the historical development or gradual evolution of the art of irrigation. The more economical modern methods have been the outgrowth of experience in the use of less effective systems. Taking these in the order of development, the first step in artificially applying water to the ground may be considered that of wild flooding, where water has been turned to the fields and allowed to find its way across them. If these fields are nearly level, there will be a fairly uniform distribution of the water; if, however, they are undulating or have low spots, it is obvious that these low places will receive too much water and if efforts are made to raise this to the higher points, the crops on the lower places may be drowned out. This is simply an imitation of the work of nature in overflowing the low-lying alluvial plains in times of flood.

Next in order, after ordinary wild flooding, comes the flooding of areas within checks or borders, consisting of low dikes or ridges of earth, holding the water in smaller divisions or portions of the field, forming little ponds of a few rods or feet in width. The next development was probably that of running the water through furrows or between the rows of planted crops. There are almost innumerable variations of these three principal methods of flooding, checks, and furrows, but for present purposes this general distinction may be observed.

Flooding.—The methods of applying water to the fields by flooding, as previously stated are largely those of nature and may be considered as the most primitive and consequently most wasteful methods of bringing water to the crops. The degree of waste, however, is reduced in proportion as the fields are carefully leveled and prepared for the flooding. With skill and care, it is possible to apply water quite economically, but as a matter of fact, such skill and care generally are not employed where flooding is ordinarily practiced.

Checks.—Irrigation in checks is a development of the methods of flooding, such that the field to be watered is laid off into relatively small tracts or compartments each surrounded by a small ridge, usually built with sufficient breadth at its base and such gentle slopes that the ordinary wagons and cultivating machines can be driven over them. As practiced by various primitive peoples and by the Mexicans, these fields or lands are made quite small, sometimes not more than a rod or two in width, the surrounding dikes being thrown up by hand with great expenditure of time and labor. The water may be introduced into one of these shallow basins or checks, usually the highest or nearest to the distributing canal, and then drawn in succession from one field to another by cutting the bounding or intervening levees.

Under another system, head ditches may be provided, by which a considerable number of these checks or lands can be filled with water at the same time and instead of being drawn off from one of these basins to the next, the water is allowed to stand until it soaks into the ground.

In certain parts of the country, especially in the San Joaquin Valley of California, large quantities or "heads" of water are used, and irrigation is rapidly accomplished, this being possible because of the careful leveling of the ground between the checks. The following statements from Mr. A. Griffin, formerly engineer of the Modesto Irrigation District, give a description of the methods and of the use of "square" checks and "strip" checks:

"Square check" or "level check" is the term applied to checks that have been made approximately level and are designated as "square" from the fact that they are usually rectangular. The best practice is to make them level to within a variation of 0.2 foot. In leveling it is not uncommon to make cuts and fills of one to two feet, and in extreme cases much greater. It is almost universal practice to serve each check directly from the field lateral and rarely through another check.

Checks are given an area of one-half acre to two acres, although the three-quarter and one-acre checks are most popular. Boxes for delivering water into the checks are made from 18 inches to 8 feet in width and capable of delivering as much as 15 or 20 cubic feet per second. Probably an average width of box is 4 to 5 feet, delivering 4 to 8 second-feet to the check. It is customary to deliver water to a number of checks at one time.

The average delivery to an individual irrigator in portions of the San Joaquin valley is 12 to 20 second-feet. There are some irrigators who can take care of 40 to 50 second-feet. The districts requirements in California do not limit the head which an individual may use except by proportioning it. The only requirement is that irrigation must be at the rate of three acres per hour and in times of scarcity the requirement may be raised to four acres per hour. It is quite possible that this may soon become a regular requirement. This has been developed gradually from the original requirement of one acre per hour. It is the increasing strictness of these requirements that has forced the present excellent checking practice.

Much of the irrigation practice is far in advance of the requirements, and rates of irrigation of from 4 to 6 acres per hour, and in some cases with large heads, of 10 or more acres per hour, are not uncommon. At the same time it has been necessary to show considerable leniency to those who cannot meet the requirements through the poor checking originally done or on account of natural difficulties of soil or topography. It might seem that the time-limit requirement would merely cause the building of large ditches, and while it has caused that, yet the people have known that while they must be in shape to use a large head in times of plenty they must also be able to use a comparatively small head to good advantage in times of scarcity which they cannot do except by careful checking.

The average cost of putting raw land into alfalfa, leveled, ditched, boxed, seeded in California, is about $40.00 per acre and costs of $50.00 to $60.00 per acre are not uncommon. Some of this work can be done for $20.00 or less per acre. During the early years of irrigation—1901 to 1906—it was thought that this work could be done for $5.00 to $15.00 per acre and many people really did it. However, most of that land has been rechecked. Contour checks were largely used at one time but are rapidly becoming obsolete.

The "border," "gravity" or "strip" check is very popular on land which has sufficient, but not too much, slope for its use. The strip check varies from 20 to 100 feet in width and from 200 to 2,000 feet in length, depending upon the local conditions. The average length probably does not exceed 600 feet and the tendency will undoubtedly be to reduce the maximum lengths very greatly. Fortunately it is easily done by merely running in extra cross-ditches. It is quite common to run a field lateral 200 or 300 feet from and parallel to the high side of a piece of land and put in a tier of square checks on the high side and strip checks on the low side. The limit of slopes for strip checks are probably as low as 0.2 foot per 100 feet to an upper limit which varies with the soil but may be a great as 3 to 5 feet per 100. Practice is still developing satisfactory results from increasingly steep slopes. It is not uncommon to make level the first 50 to 150 feet of a strip check or even provide it with a slightly elevated crest at the beginning of the slope to insure an even distribution of water on the upper end.

There is little opportunity for draining the surplus water from the lower ends of strip checks so that great care must be exercised and water must be shut off at the upper end at a carefully judged time in order to thoroughly irrigate the check and it the same time have no accumulation of water at the lower end. Irrigators become expert in time and this is one of the sources of the great economy of water that goes with strip checks.

With the stricter requirements of the irrigation district in the use of water due to lapse of time there usually develops a desire of the irrigators for still greater requirements. Some of the cuts in the time allowance have really been in response to a popular demand. The man who puts his land in first-class condition and is enabled to use water economically, immediately sees that the other man who uses it wastefully is injuring him and all others, as well as himself, by lengthening the period between irrigations and by reducing the total quantity available for beneficial use. Furthermore the man who spent forty dollars to sixty dollars per acre in preparing his land has found, as anticipated, that he is saving two-thirds to three-fourths the cost of irrigation, in labor, delays, etc.; that less of his own time is occupied in irrigating; that he can get along with less help, and that he is producing better crops.

Field laterals are 4 feet, 6 feet, and 8 feet wide, with 6 feet the most common. The same figures hold for the headgates of the field laterals. It is customary to prepare ten acres for irrigation at the same rate as one hundred, although in smaller areas this rule is subject to some modification.

Strip checking is usually considerably cheaper than square checking and it is becoming customary to use this method on all land to which it is adapted. Topography determines this adaptation as it is used on all soils. Alfalfa requires water at intervals of fourteen to fifty days, depending on the soil, ground-water conditions, and other factors that are closely related to the personal equation. Two different men on the same piece of land will create widely different conditions.

Furrows.—Irrigation through furrows or small marks or lines made on the surface of the soil is usually considered as most economical of water and as requiring a larger amount of care and skill in preparing the ground and in handling the water. In this method, the water is brought to the field by a head ditch and then turned in succession into a series of furrows (See illustration)

Wooden Measuring Weir in Lateral Canal, Williston, North Dakota.

Irrigating Sugar Beets by Means of Furrows wetting from a half-dozen to twenty or more at a time. The water is allowed to flow down these furrows or grooves on the surface until it appears at the lower end. Then the supply is cut off at the upper end and a corresponding amount turned down a group of adjacent furrows.

The success of this system depends largely on the slope of the ground and the experience of the irrigator. As a rule, in the past, attempts were made to use furrows which were too long, sometimes a half-mile in length, giving an excess amount of water at the upper end of the furrow. Where the soil is relatively porous, it is desirable to have these furrows not to exceed four hundred feet in length and the entire field traversed in such way by supply laterals as to reduce the length of the furrows.

LEVELING THE LANDS

The success of any system, in respect to economy of time spent in irrigation and in economy of water, rests largely upon the care which has been used in preparing the ground and in bringing the surface of the soil to as nearly level or smooth a condition as possible. The cost of this leveling is frequently great, so large in fact as to be practically prohibitory to the ordinary settler as regards his entire farm. He usually does not have the time or means at his disposal to bring all of his ground to the proper level, but must content himself with an approximation at this.

Experience has shown that even if the farmer does not have sufficient funds to enable him to level up in advance his entire farm, yet he can make a definite gain by concentrating a part of his efforts upon a relatively small portion of the land and bring into good condition each year even as small an area as a single acre or five acres. If he follows this plan and gradually extends these improvements, in course of time he will have the entire field brought to as nearly a perfect condition as possible. In the meantime, through lack of means he must do the best he can to utilize the remaining ground, but from the outset his plans should be such that ultimately the surface will be brought to a uniform condition, thus assuring future economy in use of water and in the time of its application.

The cost of clearing and leveling the ground varies widely, from conditions where nature has left the surface on a gentle, even slope, free from irregularities and even from vegetation, to those where the ground is very irregular, cut by small gullies and covered with a dense growth of willows and cottonwood. Here the cost of clearing and leveling as, for example, on the Yuma project in Arizona, may be as high as $50 per acre or even more.

Before plowing the fields the knolls should be taken off with a Fresno scraper. If the land can be plowed without first watering, it is preferable to do this as better results can be obtained in leveling and "floating" as it is commonly called. The leveler may be built of 2×8-inch timbers about 6 feet wide and 18 feet long. It is dragged across the field to break down the small clods, fill up depressions and smooth the surface. For best results, the ground should be harrowed after plowing and before using the float. It is important to see that all the land is turned over. In countries where there is any considerable amount of snow, the ground if plowed in the fall should be left until spring before leveling, in order to catch light drifting snow. Then as soon as the ground is sufficiently dry to be harrowed and leveled, this is done. On the other hand, if the ground is plowed in the spring, it should be harrowed immediately and not left overnight. This is for the purpose of forming a top mulch and to prevent the drying out of the soil.

On very sandy lands where there are frequent high winds, the ground may be leveled by the use of a harrow, leaving a rougher top surface. If, on the other hand, the soil is liable to pack and it is necessary to irrigate the crop to bring it up, a light harrow or corrugated roller should be used in breaking the top crust, permitting the light and air to penetrate the soil.[1]

SIZE OF IRRIGATION HEAD

The general tendency on most new irrigation projects is to attempt to use a rate of flow of water for irrigation too small for economy of time or water. It is well known that a small stream such as that from a pump of a windmill does not flow in an open ditch many rods away from the well but is lost in the porous soil. Thus although the windmill may continue in operation day and night and in the course of months pump enough water to irrigate several acres, yet the actual effect of the irrigation will only be seen over a few square rods. If the same quantity of water is held in a reservoir or earthen tank and allowed to flow out at intervals in a large stream, it is possible to irrigate a considerable body of land.

If we imagine that the small stream of water from the

[1] J. M. Jump in *Reclamation Record*, June, 1915, p. 262.

windmill pump is gradually increased in volume it can be readily seen that a greater and greater area can be covered as the water flows more rapidly. There is less proportional loss in the soil, with a large stream than with a very small one. When the stream increases in volume to about 3 cubic feet per second, it is of such size that it taxes the ingenuity of the inexperienced irrigator to keep it within bounds and with 5 second-feet the average man is quite content. However, it has been found that a still larger volume of water could be handled and with added experience an irrigation head as large as 15 or even 20 second-feet as before stated, may be used under favorable conditions. Assuming that an irrigation head of 10 second-feet can be effectively handled, it can be demonstrated that with skill and care more than ten times the area can be irrigated successfully than with 1 second-foot. The work can be done in less than one-tenth the time.

The limit of size of an irrigation head is dependent upon the character of the soil, its slope, the kind of crop raised and especially the skill of the irrigator. With relatively firm soil, which does not wash easily, and with gentle fall in the fields which have been successfully covered with alfalfa, it is possible to irrigate rapidly with the largest irrigation heads of say 15 or 20 second-feet or as stated by Mr. Griffin on page 239, up to 50 second-feet by flooding. With looser soils and greater slopes far smaller heads must be used. In the case of orchards or crops cultivated in furrows the irrigation head may be subdivided into a number of small streams each flowing down its appropriate furrow, the amount being made proportional to the length of the furrow and the steepness of the slope.

There is no one point upon which there is probably wider diversity of opinion among irrigators than upon the size of the irrigating head required for economical use of water. So much depends upon the experience of the farmer, the preparation of the ground and the size of the structures that it is not possible to lay down any hard and fast rule. In general it may be said, however, that on most of the irrigation systems the original plans contemplated using heads now considered too small for economy of water and time. Most of the older structures should be replaced and the entire system revised before high economy can be reached. Nothing increases the duty of water more than having the water "bunched" and handled in a sufficient number of farm head laterals so that the irrigator can deliver a large head and rapidly cover the land.

Every reasonable attempt should be made to give each farmer as large a head of water as he can handle under the conditions of soil, slope of ground, and structures. The average man on a 40-acre tract tries to irrigate from the upper end clear through to the lower end. As a consequence he uses much more water than is necessary, an excess being applied to the land near the lateral and too little at the far end. Experience has shown that there should be from 4 to 6 head laterals on every 40-acre tract, dependent upon the slope of the ground, but sufficiently near together to permit the full head to be used and water carried in a short interval of time from the upper end to the lower end of each furrow.

As an example of the change from small to large head used in applying water for irrigation, there may be quoted a case on the Pecos River in New Mexico, where at first the distributing system was small and the checks or portions of land to be irrigated were usually in small plots, on an average of about four plots or checks to the acre, being about 30 feet wide and 330 feet long as habitually built by Mexicans. Water was turned into each check by making a cut in the side of the earth distributing lateral and the water was shut off by filling the hole in the bank with earth. The first improvement made by Manager L. E. Foster was to put in a wooden gate so that large heads could be controlled. When this was done, a large amount of water could be allowed to rush into the check and over the ground until it reached the lower end. With this larger head it was then quickly seen that these checks or basins were too small, and should be enlarged to include at least an acre in each.

Under the old system, a Mexican irrigator required 6 days and nights to irrigate a 40-acre tract, being paid about $20 for the work. With enlarged heads and division into larger fields, this 40 acres could be watered by one man and a boy in 15 hours. To do this, it has been necessary to enlarge the laterals leading to the farm from the canals to carry from 20 to 30 second-feet of water, these being from 6 to 7 feet wide at the bottom. The checks or fields are made 60 feet wide and 660 feet long, or double the former size. The openings from the farm canal are 3 feet across and two of them are provided so that 20 cubic feet per second can be used at once, irrigating four of the above-described checks in an hour, covering the land to a depth of 4 inches. In an instance given, with this change tactfully worked out by the manager, 64 acres of alfalfa then standing 8 inches high were irrigated in 12 hours and with little difficulty with the water.

Success with large heads of 15 to 20 cubic feet per second and the consequent saving in time and greater economy in the water is dependent on securing field laterals of adequate size, strong banks, which are well above the grade of the canal, check gates at necessary intervals across the distributary and wooden or concrete gates of suitable size to conduct the large head from the distributary to the field. A poorly constructed system necessarily results in disappointment and waste.

The theory of a large head of water of say 10 to 30 feet is that it can be confined to one border of 60 or 80 feet in width and be poured quickly over the land, the size of the head being dependent necessarily on the slope of the particular tract. It may be possible to run water in this way over the entire length of an 80-acre tract, but the best practice seems to be to have several small distributaries to the 40-acre tract.

MEASURING TO THE FIELDS

The irrigation manager usually finds on his project that there are certain general practices which have been widely adopted in the use of water such as by flooding or furrow, and that he can improve these only by the exercise of patience and perseverance and after he has acquired full knowledge of all of the conditions, not merely those of soil, climate, and crops, but of the irrigators themselves. There are certain general impressions which usually prevail, to the effect that the principal object of irrigation is to keep the soil very nearly soaked in order to make the greatest plant growth, and that the increase in yield will be in proportion to the increase in the amount of water applied. This fallacy is widespread and even though many experiments have been made and demonstrations given of the fact that the yield is not in proportion to the amount of water applied, but sometimes almost the reverse, yet the average farmer is fully convinced that the more water the better and that if he pays for the water, it is to his interest to put on the field all that he can get.

The only way by which this fallacy can be corrected is that which comes from accurate measurements of the amount of water turned in the field and comparisons with the crop production. The end to be attained is not wholly that of extending the use of the water which may be available, and thus increasing the acreage, but is also that of securing the highest efficiency in the production of the crops. The necessary facts to make this demonstration can be secured only by careful measurement and by using some standard measuring device. By taking the results of these measurements and by comparing the crop yields and then discussing the matter with the farmers, it is possible to bring these facts to their attention in a way such as to convince them that there is a gain to the individual by greater care in the use of water.

Agricultural experts have found,[1] that the best total yields of wheat, oats, and corn were obtained when the soil was kept approximately equally moist throughout the season, and that with a very small water supply, two irrigations were better than one. It was also found that these crops needed a fair irrigation at the time when the seed was in the process of formation, as there was danger of the seed shriveling if an insufficient amount of water was then supplied. Ample water applied at this time usually resulted in a larger yield of grain, and an

[1] Utah Agricultural College, Experiment Station, 1912. Bulletins 117, 118, etc.

excess applied after this time, resulted in increase of straw.[1]

As stated on a previous page, in many parts of the arid West, it is the practice to use the flood water in fields or borders which are too long. One experiment, for example, shows that in the case of a field fifty feet wide and about one-half mile long, this was divided into seven equal divisions. A stream or head of water of $2\frac{1}{2}$ cubic feet per second was maintained and it took nearly an hour and one-half to reach the end of the first division, there Teing applied two-thirds of an acre-foot of water per acre. bhis was a good irrigation and if the water had been stopped there and conveyed around this portion of the field to the next portion without running over the land just irrigated, economy would have resulted.

In the case of this experiment, however, as the water flowed from one division into another, the length of time increased until at the last division, it took 7 hours to complete the irrigation as compared with less than $1\frac{1}{2}$ hours on the first portion. During that time a depth of $1\frac{2}{3}$ acre-feet per acre was applied, if this were considered as uniformly spread over the entire fields. If the several divisions had been irrigated individually, it would have taken only about $9\frac{1}{2}$ hours with a uniform depth of water of $\frac{2}{3}$ acre-foot per acre and a saving of 40 per cent. of the amount of water.

In one sense, it is as important to measure water as it is to cultivate the land. The problem as above stated is not only one of economy in the use of water, but one

[1] *See also* "Effects of Variation of Moisture Content on Certain Properties of the Soil and on the Growth of Wheat," by Franklin S. Harris, Cornell University, N. Y., Bulletin 352, Sept., 1914.

of increasing the crop revenue from the farm. This is a point which must be continually emphasized with the irrigator, namely, that it is the object of the management, as before stated, not merely to economize water in order that others may obtain it, but to help him individually in getting a large and more valuable crop production through such economy in the use of water. This is what appeals to the irrigator; it is not the benefit that will come to some other man, or to the community, but that which will accrue directly to himself. It is fortunate that this direct personal interest is coincident in this case with the larger interests of the community. It may be stated as a general truth that where water is plentiful, it is used wastefully, and the crop production is correspondingly small and poor. Where water is scarce, there is usually great care, and the values of the crops are correspondingly increased.

Closely connected with this measurement of the head or quantity of water and the total amount put upon the crop, is that of making the charges of annual operation and maintenance based upon the amount of water used. This is the most effective argument for economy. While a man may be doubtful as regards the increased yield which comes through careful use of the water, he can have no question whatever about the advantage to him of paying for a less amount of water than that which he would take on first impulse if it were furnished without reference to price. This is one of the strong arguments for requiring a payment in advance for excess water. A man who has made up his mind that he would like an extra acre-foot, when he comes to actually making the payment in advance, concludes that probably after all, he can get along with half an acre-foot and that possibly the manager may be right in saying that with this less amount he can produce good crops. The reasoning ability of the individual is greatly quickened through touching the pocket nerve.[1]

SUBIRRIGATION [2]

The term subirrigation is used to indicate the supplying of moisture to vegetation artificially by means of underground system. This method of application is attractive to those who have had little experience with it but is difficult and expensive to apply successfully except under certain favorable natural conditions.

When subirrigation has succeeded the following natural conditions exist: (1) a surface soil which possesses high capillary power and will permit of rapid lateral percolation; (2) an impervious under stratum; and (3) a uniform surface topography which will permit an even distribution.

In a few localities of the United States it has been found that after running water on the surface of the ground through earthen supply ditches for a few months or years the land has kept moist by the seepage of these ditches. Gradually it developed that surface application of water became unnecessary, as this land was being subirrigated; that is, the water was sinking to, and traveling along, an impervious stratum, thereby being distributed beneath the surface where it was brought up slowly to the plant roots by capillarity.

In a few localities subirrigation has been practiced successfully by distributing the water through under-

[1] *See* Utah Bulletin No. 118.

[2] From circular of U. S. Department of Agriculture.

ground pipes, but this method has not reached favor for any growth except shallow-rooted plants. There are various pipe systems in use; for example, one consists of a continuous pipe laid in a trench by a machine. This pipe injects the water into the soil through tubes placed in the top of the pipe. Over each tube is placed a portion of cement pipe convex side up, to prevent earth and roots entering the tubes and stopping up the tile. This system and others are still in the experimental stage.

Subirrigation has reached its most successful state in the truck regions of Florida and California. The following data relate to a Florida system which consists of a water supply delivered to the highest portion of the field to be irrigated. From this point a main feed pipe leads to a distribution lateral system which in turn terminates at a drainage ditch or tile.

The lateral system consists of a series of parallel pipe lines made of common cement or clay drain tile three inches inside diameter and twelve inches in length. At points in each lateral where it is desirous to check the water, a cement stop box is located for use in operation.

The correct spacing, location, and laying of the laterals is most important to the success of a subirrigation system, when natural conditions permit the use of this method. The spacing is determined principally by the texture and powers of the soil to convey water within itself. In the sandy soils of Florida the spacing is eighteen to twenty-four feet. In heavy soils this distance would be much less.

Wooden plugs are used to control the flow or irrigation throughout the tile system. Generally, each hole in the weir wall or pipe connection will be fitted up with a system of plugs, consisting of a large hollow plug which fits the opening and a smaller solid plug fitting into the hole in the larger plug. By operating this system of plugs different-sized streams may be obtained.

The operation of a subirrigation system is comparatively easy when the construction has been planned properly, and is done carefully. Water is turned into the main feed pipe and streams allowed to flow into the lateral, according to the amount needed. Each irrigator must learn by experience the quantity required. Subirrigation is slow, the rapidity depending mostly upon the porosity of the soil, therefore, each lateral must be supplied according to that rate that the soil will take the moisture without oversaturating the land along the tile line before the water can travel outward and meet between the individual laterals. The tendency in many of the subirrigated fields especially when flowing wells are used as a source of water supply, is to overirrigate by allowing the water to run through the tile continuously until the waste is discharged into the drainage system. This puts an excess of moisture into the soil and in draining out results not only in a loss of water, but leaches the sandy soils of soluble fertilizer.

An underlying impervious stratum which tends to hold the moisture in place is the condition for success in subirrigation. This stratum may be hardpan, clay, rock, or the water table. In other words, there must be a bottom to support the water while it makes its slow transit laterally and upward through the soil, otherwise there would be a tendency toward a heavy loss by seepage before lateral distribution could take place.

The generally high first cost of a subirrigation system, ranging from \$75 to \$125 per acre or even more, makes it necessary to estimate carefully on the value. Practically all of the subirrigated land in Florida needs drainage before it can be farmed, therefore, a large proportion of the expense for the tile system can be properly charged against the drainage. The subirrigated sections are the truck sections also, where the value of crops each year is large and will pay interest on a heavy reclamation investment. The plants cultivated should have such short root length that they will not enter the shallow-laid tile, obviating many difficulties in maintenance. Celery, lettuce, cabbage, potatoes, and nearly all other truck crops are grown by subirrigation.

CARING FOR WASTE WATER

The necessity of making provisions for taking care of the excess waters is obvious. This is a matter to which the management must give continuous attention as being correlated with methods of applying water to the crops. In some respects, in the matter of water supply an irrigated field may be considered similar to a town. As soon as an adequate supply of water is provided for a town and the old system of obtaining water from wells is partly done away with, then comes the immediate need for drainage or for a sewage system to take away the waste water.

Theoretically, the waste from a gravity water-supply system should not be greater than that from the old preëxisting methods, but as a matter of fact, with the better facilities for obtaining water at all times, there is more waste, and provision must be made for its disposal. This is frequently overlooked and in improving the regularity of water supply and distribution sufficient attention is not always given to the fact that as soon as the water is adequate in quantity then there will be more waste. Hence, the necessity arises for studying the rise of ground water and the methods of relieving the soil of the excess amount of water.

LATE FALL IRRIGATION

Closely connected with the methods of applying water is the question of time of year when irrigation should be discontinued. Whatever date is set, there are usually a considerable number of irrigators who request that water be furnished still later to enable them to wet the fields for fall plowing or to fill ponds for furnishing water to stock. The fall pasturage also is often an important item and to maintain this in good condition, water must at times be kept in the canals after the date has arrived when it should be turned out and the fall clearing and repairs begun. There is thus usually a conflict of interests between certain individuals and of the community. The latter, of course, is concerned in shortening the length of the irrigation season, thus reducing the seepage to the lands and decreasing the operation costs.

The quicker irrigation is terminated, toward the end of the crop season, the less is the cost of operation and the cheaper the annual cost of maintenance. Even more important is the lessening of possible injury to lands by prolonged seepage; the sooner the water can be turned out in the fall and the canals allowed to dry, the quicker the water table will drop and the less the possibility of injury to the agricultural fields.

Balanced against this is the question of value of late fall irrigation. With certain soils there is undoubtedly a crop gain due to late application of water. In particular, on the lands in western Nebraska, experiments show that there was an increase in yield of many crops of about twenty per cent., due to water applied in September. The conclusion reached is that with the possible exception of potatoes, the yields of all crops were increased by fall irrigation sufficiently to more than pay the cost of the work. It should be noted that in this locality the rainfall from October to March is usually so light that the soil is frequently too dry in the spring to promote germination and support the early growth of spring-planted crops. Under these conditions it is easy to see that by irrigating the land in the fall after the crops are harvested there should be an improved condition wherever the soil is of such character as to retain a portion of the water until spring. If, however, the soil does not retain moisture, the time and labor of fall irrigation may be lost.

This condition illustrates the fact that careful consideration must be given to the soil as well as to the climatic conditions, and that the irrigation manager must be thoroughly informed before he can intelligently apply some of these general rules.

CHAPTER XIV

THE PRODUCTS

Crop to be Studied.—The irrigation manager must bear in mind continually that the object of the irrigation system is to produce crops which can be sold or disposed of to advantage by the farmer. While it is not directly his duty to intervene in these matters, yet to attain success, he should be ready at all times with helpful suggestions. He should take the initiative in a quiet way toward directing the attention of the farmers toward improvements such as suggesting crops better adapted for the soil or climate, securing better markets for these crops, or working up the raw products into the more valuable forms.

In this work, the state agricultural colleges and various bureaus of the United States Department of Agriculture are taking action. Through farmers' institutes, through meetings held, particularly in the winter, through the daily or weekly papers, and in many other ways the irrigators are continually learning better methods. There is resulting a gradual development of better crops and markets. Through his broad knowledge of the conditions of water supply and related physical facts, the irrigation manager, more than any other man, is in a position to be of aid and to supply the initiative which is sometimes lacking.

Relative Value of Irrigated Crops.—There is a great difference in relative cost and value of the various irrigated crops, not only with reference to each other but as compared with those grown without irrigation. There has been an exaggerated idea of the value of irrigated crops. This is due largely to the widespread advertisement of the advantages of irrigation for the purpose of attracting purchases of irrigation securities or of irrigated lands. While it is true that by irrigating larger and more certain crops can and should be had than by depending upon rainfall, yet it does not follow that the greater part of the irrigators have made use of these advantages to their full extent. Many have been prevented from so doing through lack of capital or experience. Thus the average crop values obtained, taking in account all areas, whether well handled or not, is far less than popularly supposed.

The following table gives a fair conception of the *average* value of irrigated crops as actually obtained on the Government projects. This average, $23.50, does not vary widely from that prevailing throughout the arid West. It would be a great mistake, however, to judge the success of irrigation by this average, because as before stated it is greatly reduced by the inclusion of thousands of acres of new lands poorly handled and from which little return was realized. It illustrates, however, the actual condition, and when compared with the totals given by successful irrigators, indicates that great advances may be made when larger knowledge is diffused and greater skill acquired.

There is also a great difference in the relative cost and value of the various irrigated crops, especially with regard to the amount of capital and labor required to produce and market them. The tendency of the farmer

IRRIGATION AND CROP RESULTS ON GOVERNMENT RECLAMATION PROJECTS, 1914 *

Project.	Irrigable Acreage.†	Irrigated Acreage.	Cropped Acreage.	Value of Crops. Total.	Value of Crops. Per Acre Cropped
Salt River	187,112	173,030	169,719	$4,039,079	$23.80
Yuma	60,000	25,207	22,568	709,409	31.43
Orland	14,300	7,354	6,540	176,331	26.99
Uncompahgre Valley	52,338	33,873	33,091	870,381	26.30
Boise	207,000	......	......	....	.....
Censused lands	....	64,767	58,064	1,033,447	17.80
Lands not censused ‡	....	18,823	16,868	300,140	17.80
Minidoka	117,090	......	......	....	.....
Gravity unit	....	45,730	39,138	661,796	16.91
S. S. Pumping Unit	....	35,788	33,512	558,059	16.65
Huntley	28,808	17,068	17,068	454,583	26.63
Milk River	13,440	2,201	2,163	34,618	16.00
Sun River	16,346	6,613	6,561	106,594	16.25
Lower Yellowstone	36,250	5,743	5,621	96,707	17.20
North Platte	91,504	60,532	59,536	890,202	14.95
Truckee-Carson	52,039	39,516	39,285	441,018	11.23§
Carlsbad	20,261	12,690	10,731	237,663	22.15
Hondo	1,224	1,224	1,172	21,458	18.31
Rio Grande	40,000	28,442	27,302	1,160,720	42.51
N. D. Pumping	12,239	1,056	1,045	36,440	34.87
Umatilla	17,000	5,102	3,013	88,614	29.41
Klamath	38,000	24,440	24,440	347,344	14.22
Belle Fourche	68,852	37,454	36,709	461,188	12.56
Okanogan	10,099	7,740	3,180	104,575	32.88
Yakima:					
Sunnyside Unit	81,807	64,052	49,273	2,858,845	58.02
Tieton Unit	34,000	20,600	15,920	472,480	29.60
Shoshone	41,166	22,226	20,905	313,826	15.01
Total	1,240,875	761,271	703,424	$16,475,517	$23.50

* Data are for calendar year (irrigation season), except on Salt River project, Ariz., data are for corresponding agricultural year, October, 1913, to September, 1914.

† Area Reclamation Service was prepared to supply water.

‡ Figures for lands not censused, except irrigated acreage, estimated from figures for censused lands.

§ $18.22 excluding 19,000 acres native pasture land at $1.21 per acre and 4,908 acres otherwise not in full production.

is to follow somewhat blindly along the same path year after year, planting the same crops in the same way, without reference to the fact that market conditions are changing and that the cost of producing a crop may be steadily increasing while the price received is slowly decreasing. This is a matter which is being given more and more attention by agricultural experts.

The irrigation manager, in connection with the collection of the statistics and through his acquaintance with conditions, should be able to make suggestions to the agricultural experts and to others such as may attract the attention of the irrigators and cause them carefully to consider whether or not certain crops, to which they are accustomed, are really the most valuable, when all of the facts are taken into consideration.

A little study or consideration of the cost and profits will show that some crops which are considered to be the basis of prosperity of the country are really not profitable in themselves, or that when all facts are taken into consideration, they are not yielding as large profits as others. It is only by careful study of these details and unprejudiced consideration of the subject such as comes from careful farm management, that it is possible to arrive at any valuable conclusion in this regard.

It often comes as a decided shock to some of the older farmers to learn that the crops, concerning which they have been so sure, are really not profitable and have been consuming their investment instead of adding to its value. As illustrative of this condition, is the case of an old farmer who for years had been raising wheat and had come to have quite a reputation as a farmer.

His lands had gradually advanced in value and he had acquired a comfortable home. To his great astonishment, his banker, who was fully aware of the conditions on the farmer's place, showed him one day that as a matter of fact it was not the profits of his wheat which had made him relatively well-to-do, but it was really the thrift of his wife and the sale of poultry or small livestock which she had raised that had made the farm a success. The wife had used some of the grain and other products, had kept a considerable number of poultry, had brought eggs or chickens to town every time she came, had always something to sell in this way, and had a credit at the various stores where she disposed of these products. As a matter of fact, it was her earnings, the use of the by-products, and the gradual increase in land values, and not the sole efforts of the farmer, which had been the foundation of the success of the family.

Profit.—The profits on an irrigated farm come mainly from what in ordinary manufacturing is known as the by-products. The daily, customary routine of producing the common field crops does not yield a profit much above the wages of the ordinary day laborer. It is in the working up of the side lines, the manufacturing of the heavier products such as hay and grain into meat, butter, and eggs, and especially the utilization of the spare time or intervals which otherwise would be wasted in non-productive occupations by the farmer and his family. By getting up early and working late, by utilizing the labor of the children in ways which do not stunt their growth, by using all the otherwise waste products or smaller fruit and vegetables of the farm, and by feeding to the domestic animals and poultry everything which otherwise might be lost, the net earnings are increased. In this way only does irrigation farming become profitable. The gains come as a rule not through the larger or ordinary field crops. Thus farming under irrigation is usually successful when confined to the smaller tracts where the whole family can be employed and it is independent of the hired man.

Specialization.—The success of irrigation in any community depends largely upon specializing in some one particular crop or variety, one which in some particular gives that locality a notable advantage over other places. This may be through ability to market the products earlier, or through some peculiar quality such as that of flavor of fruit or accessibility to market. For example, the Rocky Ford, Colorado, melons have made the community prosperous. Their popularity is the result of certain qualities developed by the skill of a small group of men who produced them.

The Greeley potato at one time was the foundation of success of that part of Colorado. This was also a result of certain conditions of soil found at that time to be peculiarly favorable to the development of the potato, and later lost through neglect. In the same way, the Grand Junction, Colorado, peach, and the Hood River, Oregon, apple, are at the basis of the prosperity of communities of considerable size.

If in these communities, general farming had been undertaken, and there had been no one to discriminate between the profitable and less profitable crops, it is probable that these communities would have gone along as other agricultural people, with relatively small earnings; but because in each place there was a man or group of men who had the power of observation and the initiative sufficient to follow up the discoveries, each of these localities has become famous in its way.

Deterioration.—Accompanying specialization there is always a danger of deterioration through lack of skill or of care in keeping up to its highest standard the particular crop grown in any given area. This is the result frequently of increased prosperity and of indifference, which results through lack of competition in the market for these crops. Deterioration of crop is also closely connected with deterioration of soil, due to excessive use of water or to neglect of some of the precautions which are essential for success in agriculture.

As has been pointed out by writers on the subject, the ease with which crops have been produced on some of the soils of the West has caused the settlers from the humid areas to lose the skill which through necessity they had attained under the older and harder conditions in the East or in Europe. They have become not real farmers but "soil sappers" and miners. The work of soil depletion and of crop deterioration has been continued with little check so that, as stated by agricultural experts, the history of American farming, except in some notable instances, is a record of profligate waste of natural resources and of soil fertility. This waste is being repeated on an extensive scale under the irrigation system in the western part of the United States.

Reduce Waste.—The lesson to be emphasized at all times is the vital importance of reducing waste. While all reasonable efforts should be made to grow larger and better crops, this must be accomplished by the practice of those principles of thrift or economy which are essential in every steady occupation. It is not the farmer who produces the heaviest crop yields per acre who is most prosperous. The principal difference between the man who grows the largest crops and who has at the end of the year the largest net increase is not in the income, but in the difference between income and outgo. The vital point is that the one man saves more.

To save more does not necessarily mean to earn money, but to save in time and material by better planning and performance. The man who saves more follows in general the following practices:

He does not try to farm 160 acres when he can better handle 80 acres.

He does not sacrifice quality for quantity in crops and livestock.

He does not put good feed into poor quality livestock.

He does not hire help to raise unprofitable crops.

He does not hire help and then neglect to furnish suitable tools.

He does not buy good tools and then neglect them.[1]

An excellent scheme for enforcing these and similar rules is that of a "No Wasters Club." The members visit each other in a body and discuss causes of waste, at the same time trying to point out methods of farming which could be improved. An organization of this kind efficiently conducted must be of inestimable value to its members.

Experimental Farm.—Every irrigation manager or other well-informed person connected with the initiation of an irrigation project, is impressed with the importance of having correct information given to the newly arrived farmers, concerning the capability of the soils, the best crops, and the proper methods of distributing water.

[1] I. D. O'Donnell in *Reclamation Record*, Aug., 1915.

To do this successfully, requires a broad knowledge not merely of the physical conditions of soil and crops, but also of the probabilities of obtaining a good market for the particular kind of crops which are to be raised. The more the subject is studied, the more difficult it appears to the man in responsible charge. He soon recognizes that there are three distinct steps in this matter of giving correct information and advice to the farmers:

First. The experimental farm on which definite tests can be made as regards various crops grown under different conditions of cultivation.

Second. Demonstration farms, where the results of the experiments are shown to the farmers, illustrating the fact that the methods which have been prescribed can be successfully followed.

Third. Agricultural advisers or agents, who can go about from farm to farm, collect information concerning the success of the farmer, and tactfully give suggestions or advice, diffusing in this way the results attained at the experimental and demonstration farms, impressing these upon the farmer without at the same time arousing in his mind any resentment at being given unsought advice.

The experimental farm is at the foundation of success of a new project. Theoretically at least experiments should be conducted for a number of years before advice is given. Unfortunately, however, under the present methods of development, it is not possible to wait these years, and frequently advice is sought by the farmers and must be given long before the men who are supposed to know the conditions really have full and correct information concerning all details. Nevertheless, the experimental farm should be started on the project as soon as possible and carried on year by year, trying out various crops and rotations of crops, thus affording accurate information concerning the conditions for success which are encountered on the subject.

Experimental farms of this kind have usually been conducted in coöperation with the United States Department of Agriculture, or under its immediate supervision; with the state agricultural colleges; or better, by a combination of federal and state employees. The information obtained on these experimental farms has value not only to the farmers on the project immediately surrounding the experimental farms but also as adding to the general knowledge of the agricultural resources of the state. For this reason the cost of the experimental farm is usually borne by the general public, as the public at large receives the principal benefits.

It is not to be expected that these experimental farms will at once hit upon the best combination of crops and too much should not be anticipated of them; in fact, much of the best work is to a certain extent negative in character in showing that it is not wise to attempt to plant certain crops which have been successful elsewhere nor to follow certain agricultural practices which are believed by the majority of the farmers to be best simply because of the fact that they have been practiced in their former homes.

Demonstration Farms.—It is necessary to keep in mind the fact that the demonstration farms are operated for an entirely distinct purpose from that of the experimental farm. In the case of the experimental farm, it is assumed at the outset that much of the work must be, as above stated, negative in character in showing that it is not desirable to cultivate certain types of crops.

On the demonstration farm, on the contrary, it is assumed that the results attained demonstrate the success of certain practices and may be used as illustrations to enforce upon the attention of the farmers the advantages of following a certain system of crop production. The experimental farm may be valuable even if the crops do not succeed, but the demonstration farm to be of use must show results above those of the average of the community. It must seek to attain certain high standards of success, and yet at a cost such as to insure profit.

The selection of demonstration farms and the conduct of these is, therefore, generally based on an entirely different principle of procedure from that of the experimental farm. Best results can usually be obtained by making arrangements with some farmer with good practical sense and wide experience to devote a portion of his farm to the demonstration of a certain method of cultivation or of variety of crop. By making arrangements with such farmers on different areas, and on different soils, it is possible, at the minimum expenditure, to illustrate the particular kind of crop or method of cultivation. In making these arrangements, care must be taken to see to it that the farmer follows the instructions explicitly and thoroughly understands the theory on which the demonstration is being conducted.

It is to be noted in this connection that under some of the irrigation systems these demonstration farms have not proved an unqualified success. In fact, occasionally a farmer who has followed less scientific methods has been able to produce better crops. Possibly by chance he has hit on a better scheme. This should be no reflection upon the theory of good crop production; rather it is an illustration of the fact that under widely varying conditions of soil, climate, and especially of the attitude of the farmer himself, it is not always possible to produce the desired results or to anticipate all conditions. It also illustrates the point that arrangements should be made for a number of demonstration farms, so that if one does not succeed, there is probability that another will do so.

On some of the larger projects, it has been found desirable to make special inducements to practical farmers to locate within the reclaimed area with the hope that by their example they will stimulate their neighbors and that they will each create what is practically a demonstration farm.

Agricultural Experts.—The results obtained on an experimental farm or illustrated by demonstration farms will be largely lost unless it is the duty of some experienced and capable man to bring these results to the attention of the farmers. Theoretically, this could be done by publication in the local papers and by small bulletins or leaflets sent to the irrigators, but as a rule the practical farmer is very busy. He does not have time or inclination to read and is not always well impressed with the statements he thus receives. If, however, arrangements can be made by which a man, who thoroughly understands the theory and the practice of agriculture in the particular project, goes from farm to farm and personally explains the conditions which have led to success elsewhere, then the highest results may be had from the work which has been carried on at the experimental farm and on the demonstration tracts.

The first qualification for such an agent beyond professional skill and knowledge is that of tact. There is probably no one occupation which calls for the constant exercise of this valuable quality as that of approaching the average farmer who believes and sometimes bluntly states that "you cannot tell me anything about farming." He has been at it for the greater part of a lifetime and knows what he is about. Furthermore, some of these farmers resent the idea of gratuitous advice and believe that they already have a full understanding of the conditions and that the agricultural adviser, who is sometimes a relatively young-appearing man, cannot possibly possess the experience necessary to be able to give valuable facts. In a few such cases, where these agents or advisers have been employed by an irrigation company and where their advice or suggestions have been followed perhaps only in part, but with lack of success, the farmers have even gone to the point of attempting to bring suit against the company on the ground that the advice has been injurious to them, ignoring the fact that in many cases they have not observed the precautions which were insisted upon by the agricultural adviser.

As shown by experience, it is not wise to assume that the average farmer of his own initiative will visit the agricultural experiment farm on the irrigation project or will take the trouble to go to a demonstration farm even in his neighborhood, unless it has been clearly shown to him that he will derive personal advantage by so doing. The habitual attitude is that of skepticism toward any theory of farming and while many a farmer says that he knows there is an experimental or demonstration farm somewhere in the vicinity his curiosity has not been sufficiently aroused to induce him to visit the locality. He does not appreciate that some of his own troubles, those which are keeping him closely confined on the farm, might be solved if he would visit his neighbors and learn what others are doing; or that by talking with the director of the experiment farm or the man on one of the demonstration farms, he might learn the very facts for which he has been blindly groping.

The most successful agricultural adviser or agent is the man who in approaching the farmer, especially for the first time, does not pretend to any special knowledge but on the contrary assumes the attitude of one who is trying to learn from the farmer himself what are the existing conditions and what is the result of the farmer's own experience. Nearly every man is pleased to be asked his advice on familiar points, and as a matter of fact, there are few farmers but have some valuable experience in one line or another. The agricultural agent, therefore, in asking advice or suggestions from the farmer, who may be a personal stranger to him, is by no means adopting a false attitude when he asks him frankly for his advice and for his experience on a particular farm, and under the surrounding conditions. It frequently occurs that information and advice thus given to the agricultural expert may add notably to his knowledge of the physical conditions, and even more, of the human conditions to be met.

By drawing out from the farmer such information or advice as he may have, an opening is made for discussion and for giving to the farmer, even though he may be unresponsive at the outset, certain valuable ideas which sink in and later take root.

The agricultural adviser, or missionary, as he may be called, to be a success, must be something of a specialist in some one line, so that in such particular line, he may be in advance of all of the people on the project. It must be admitted that taking the people as a whole, their collective knowledge far exceeds that of the agricultural adviser; hence in order to retain the confidence of the people, the adviser must be an expert on some one point while having general knowledge of others.

The experience shows that these agricultural experts, fully equipped and competent to give advice in a new country, are extremely rare. The average farmer coming to a project must find out largely for himself the methods most conducive to success. He can be greatly assisted by suggestions, especially if these are given in such way that he thinks they are, in part at least, his own discovery. After the farmer has made some mistakes the agricultural adviser, the irrigation manager and his assistants, viewing the matter sympathetically by a few well-directed statements and questions regarding what others have accomplished, may induce the farmer to reach the desired conclusion.

For example, in one case it was evident that a farmer who was stubbornly adhering to certain methods of applying water, was not bringing about proper plant growth. It was useless to tell him of this, although the records of water delivery showed it to be a fact. When the farmer had come to a realization that something was wrong, the irrigation manager spent a little time on his farm; and, by trying certain experiments in the sight of the farmer without telling him where he was at fault, the manager led him to reach the proper conclusion for himself. No amount of argument could have convinced the farmer of this fact, but the tactful abstaining from discussion caused him to do a little figuring and gave him the joy of discovery on his own part, thus enforcing the lesson far more strongly than could have been done by any outsider. Little can be accomplished in such matters by going directly to the farmer before he is in a receptive attitude. The best results are accomplished when conditions have shaped themselves to such a point that the farmer is willing to ask a question and to give full weight to replies. Volunteered information may sometimes do more harm than good.

One of the conditions leading to greatest success in the case of the agricultural adviser is in connection with some highly specialized form of crop, for example, of sugar beet or of Egyptian cotton. In these cases the farmer has usually had little experience and is in a receptive attitude with reference to any information that may be given to him. If, therefore, a man who is a sugar-beet expert and who has been accustomed to working with the farmers, takes up this subject, the attitude of the farmer towards him is one of respectful attention rather than one of criticism as to methods. The expert introducing the cultivation of the sugar beet has thus been of great help to the farmers throughout the arid West, not merely in the production of the beet itself, but more than this, in being able to give direct and effective advice to the farmer concerning all of the related agricultural operations and the crops which may be rotated with sugar beets as well as the methods of preparing the soil and handling the sugar beet and the other crops.

In the same way, the introduction of Egyptian cotton, a practically new agricultural product, enables the expert not only to give sound advice regarding the cultivation of cotton itself, but more than this, respecting the methods of applying water, the need of water economy, and the proper handling of other crops which should be rotated with Egyptian cotton. It is through the introduction of these highly specialized crops that the largest and best development of scientific agriculture may be brought about, and the farmers may be induced to listen to the suggestions which lead to better farming and to greater economy in the use of water. For example, in the cultivation of cotton, it is generally conceded that too much water will decrease the value of the crops. This lesson once learned with reference to cotton may be successfully applied to the other crops where the losses through overirrigation are not as immediate or directly apparent as those in the case of the cotton.

Fertilizers.—At least two fallacies have been prevalent in irrigated regions: *first*, that irrigated land does not require any artificial fertilizer because of the fact that the water itself furnishes the fertility; and *second*, assuming that fertilization is needed, the same kind of fertilizer which has been found of advantage in the old home in the humid region may be used with success on the new farm in the irrigated region.

There is probably no one item of expense in which the farmer has been more extravagant or more easily deceived than that of the purchase of fertilizers. The reason is obvious, since few men are experts on the chemical and physical composition of the fertilizers which are offered on the market or on the effect of these on various soils and crops. Usually, the farmer goes into the matter somewhat blindly, appreciating only the fact that he wants something; and purchases whatever may happen to be offered. He may later discover that the fertilizer selected has been an injury rather than a benefit to his land.

As regards the first claim, namely that irrigated land does not require artificial fertilization, this erroneous statement is not heard as often as in the early days of irrigation. It was claimed by the earlier promoters of irrigation schemes that the irrigating water brought with it river silt or salts in solution which added to the fertility of the land. In this connection the fertility of the valley of the Nile was eloquently pictured. It is now understood, however, that even in Egypt, it has been found necessary or desirable to supplement the Nile water with some form of artificial fertilizer, especially that containing nitrates or phosphates. The waters of the rivers of the arid region of the western part of the United States are, however, frequently not charged with the useful salts in solution, or do not carry the silt which is at all comparable in value with the red water of the Nile. The deposits left on the ground by such river waters, if any, are often of no particular value in adding to the fertility of the soil.

Most of the soils of the arid region are deficient in humus or in organic matter, and the first step is to add this, usually by the growth of alfalfa, clover, peas, or some other legume, turning in the green crop and thus putting the nitrogenous matter directly into the ground. If properly handled, the crop production during the succeeding years is increased considerably above the value of the green crop which has been turned under.

This simple treatment is not always sufficient. It may be desirable or even necessary to supplement this by some form of fertilizer, usually the ordinary stable or barnyard manure. In the case of certain soils and crops, it has been found profitable to purchase artificial fertilizer. Before buying such material, advice should be had from experts, who fully understand local conditions, such, for example, as those employed at the agricultural experiment stations.

It should never be forgotten that the soils of the arid region are entirely different in their method of formation and in general character from those in the humid region which have been washed by the copious rainfall. As a rule, the arid soils have an excess of alkali, while those of the humid region may be somewhat acid. An elementary knowledge of chemistry will at once show that the treatment of the two classes of soil must be radically different. Yet, ignoring this fact, but having had years of experience with a certain brand of fertilizer, the farmer from the East may trust to his old experience, purchase the highest-priced material and apply it, only to find that he has not added to the value of his crops.

In connection with fertilization, attention may be called to the fact that economy of water is promoted by thorough fertilization of the soil. Quoting from "Egyptian Irrigation" by Sir William Willcocks, page 763:

> It would be a healthy innovation, indeed, if the provision of suitable manures were to be considered as an essential part of the project for providing perennial irrigation. The day is not distant, I believe, when governments which provide irrigation works will also provide manures, and sell the water and manures together, one being as essential as the other; I know well, from observation, that a well-manured field needs only half the water that a poorly manured field does; and in years of drought and scarcity manures almost take the place of irrigation. Why should there not be a manure rate as well as a water rate? Here in Egypt, the numerous ruins of old-world cities have hitherto provided manure for a great part of the perennially irrigated lands; but these are being fast worked out, and other sources

must be sought for. Farmyard manure will never suffice for the intense cultivation in this country.

The irrigation manager should at all times call attention to these striking points and the necessity of giving careful attention to each type of soil, urging upon the individual irrigators the importance of utilizing the facilities offered by the Department of Agriculture and of the state experiment station.

The commercial value, or market cost, and the agricultural value of fertilizers are in no way related. The choice of the kind of plant food to be purchased should be based on the knowledge of the needs of the particular crop and soil to be treated. Only after this is decided, should the cost of the fertilizer be considered, when the particular kind of the fertilizer supplying the ingredients desired will be selected according to its agricultural availability and cost.[1]

Cattle on the Farm.—The matter of fertilization emphasizes the necessity of having an adequate number of cattle on the farm. The average irrigator who raises the ordinary grain or root crops, or sells alfalfa off the farm, is usually impoverishing the soil and depriving the farm of its fertility. The ideal condition is that, as in the other business, of working up all the raw products into the most condensed form; not selling the bulky produce off the farm, but manufacturing it into the most valuable condition of milk, butter, eggs, poultry, pork, mutton, or beef. This means that the raising of the ordinary field crops must be supplemented by the feeding

[1] Commercial Fertilizer, by John Burd, Bulletin 245, Agricultural Experiment Station, Berkeley, California.

IRRIGATION MANAGEMENT

WATER USER CENSUS

The Water User

Name
Address
Owner or renter?
Previous occupation Previous location
Date of settlement Number of people on farm
Years experience in humid farming ; in irrigation farming

The Farm

Subdivision Sec. T. R. M.
Subdivision Sec. T. R. M.
Subdivision Sec. T. R. M.
Acres in farm, total ; irrigable ; seeped ; drained
Acres cleared and leveled ; cost per acre of clearing and leveling $
Total cost of all other improvements, $
Purchase price of farm without improvements, $
Present value of farm with improvements, $

The Stock and Equipment

Kind.	Number.	Value.
Horses		
Mules		
Cattle		
Sheep		
Hogs		
Fowls		
Hives of bees		
Total		
Equipment		$
Grand Total		$

The Crops

In listing crops (other side): under BEANS include white and brown beans raised for market for human food; under CANE include sugar and sorghum canes; under CORN, INDIAN, include all varieties of Indian field corn; under CORN, SORGHUM, include the Sorghum family, such as Kaffir corns, Milo maize, Jerusalem corn and Egyptian rice corn, raised for grain; under CORN, FODDER, include stover or fodder harvested either from Indian or Sorghum corns; under FRUITS, SMALL, include berries, currants, grapes, cherries, plums, olives, dates and figs; under GARDEN, include the family garden and all truck crops grown for market and not given in the printed list; under PEAS, include all threshed field peas, soy-beans, cow-peas and the like; under WHEAT include all common wheats, macaroni wheats, spelt and emmer raised for grain; under *EACH CROP* include any acreage on which the crop failed and compute the average yield from the total acreage of the crop.

Remarks

______________191_____ ____________________

Water User or Rider.

THE PRODUCTS

Kind.	Acres.	Yield.			Value.		
		Unit.	Per Acre.	Total.	Per Unit.	Per Acre.	Total.
Alfalfa Hay		ton			$	$	$
Alfalfa Seed		bu.					
Apples		lb.					
Barley		bu.					
Beans		bu.					
Beets, Sugar		ton					
Cane		ton					
Clover Hay		ton					
Clover Seed		bu.					
Corn, Indian		bu.					
Corn, Sorghum		bu.					
Corn, Fodder		ton					
Cotton		lb.					
Flax		bu.					
Fruits, Citrus		lb.					
Fruits, Small		lb.					
Garden		—	—	—	—		
Hay *		ton					
Hops		lb.					
Millet Seed		bu.					
Oats		bu.					
Onions†		bu.					
Pasture		—	—	—	—		
Peaches		lb.					
Pears		lb.					
Peas		bu.					
Prunes		lb.					
Potatoes, C.‡		bu.					
Potatoes, S.§		bu.					
Rye		bu.					
Wheat		bu.					
Miscellaneous							

Total acreage		Total value $
Less arceage counted twice		Average value per acre $
Net acreage cropped		

* Except alfalfa and clover hay.
† Onions raised for market.
‡ Common. § Sweet.

Total irrigated acreage of:

Non-bearing orchard		Acres
Young alfalfa (no crop)		"
Ground fall-plowed		"
Miscellaneous		"
Total		

Less acreage of crops grown in non-bearing orchard, young alfalfa ground fall-plowed, etc.		"
Net area irrigated without crop		"
Net acreage cropped (see above)		"
Total irrigated acreage		"

of cattle, giving employment to the farmer and his family throughout the year, rather than concentrating his work during the summer months, and losing the value of his time during the other months.

The farmer, in fact, is a manufacturer, and like the manufacturer must study all economies of time and materials, not permitting his equipment to lie idle for a great part of the year for lack of use. By feeding his own crops during the winter, by attending to all the small economies of the farm, by sending to town from time to time the products above noted of eggs, poultry, etc., there is a steady gain as compared to the farmer who raises one or two kinds of crops, sells these, and is only partly occupied during the winter. He, as a rule, hardly makes a day's wages, taking the year through and comparing one year with another.

Crop Reports.—It is of great importance to the project manager that he have taken at the end of each season a full statement regarding the general financial condition of the farmers and particularly of the approximate amount and value of the crops which have been raised. Without definite information of this kind it is impossible to state definitely what progress is being made, or to bring to the attention of the water users those improvements or economies which are the foundation for success. The crop reports can generally be most easily and effectively taken by the canal-riders and other men who are thoroughly familiar with the country, who know the farmers, and who can readily prepare answers to most of the questions, supplying details of the crop report for each farm by a few interrogations. It is desirable to avoid as far as possible anything which is inquisitorial in character, but on the contrary to fill in the blanks from general knowledge and only ask such questions as may be regarded as proper by the farmer.

In obtaining these crop reports, the effort should be made to limit the statements to a few of the larger facts which are readily obtainable. The temptation is always to expand along various lines and finally reach an elaboration which results in breaking down the entire system. Simplicity, therefore, must first be sought and then, if necessary, general conclusions can be added to supplement the simple facts which are obtained; it is probably better for the project manager to elaborate on these details himself rather than to try to obtain very full or complete reports concerning each farm.

The principal statistics which are needed include first the human element, that is, some facts concerning the farmer, the size of his family, his previous occupation or location, the number of years he has been on the farm, and the number of persons in his family, combined perhaps with a brief statement as to his previous experience as an irrigator or in dry farming.

Next in order comes the size of the farm, the irrigable area, the amount which is seeped or injured by alkali, the number of acres cleared and leveled, the cost of improvements, and the purchase price or value of the farm.

Then in logical order are certain questions concerning the kind and number of horses, cattle, hogs, fowls, etc., on the place, and the total value of the equipment.

Taking up then in some detail the character of crops raised, we have in alphabetic order, alfalfa, apples, barley, beans, etc., giving the yield per acre in tons or other units and the value per acre. It is necessary to provide a blank with a considerable number of spaces

WATER USER OR PROJECT...Year of 19........

		Crop.	Area, Acres.	Unit of Yield.	Yields. Total.	Yields. Per Acre. Average.	Yields. Per Acre. Max.	Yields. Per Acre. Min.	Values. Per Unit of Yield.	Values. Total.	Values. Per Acre.
Irrigated for	Production of this crop										
		Less duplicated areas									
		Total cropped		Total and average							
	Other purposes										
		Less duplicated areas									
		Total other purposes									
Grand total irrigated											

Areas.	Acres.	No farms	Per cent of Project.
Total irrigable area farms reported			
Total irrigated area farms reported			
Under water right applications			
Under rental contracts			
Total cropped area farms reported			

INSTRUCTIONS FOR CROP YIELD REPORT

1. The crop yield report shall be included in the annual operation and maintenance report, and an *advance copy* shall be sent to the Director as soon after its compilation as possible.

2. All crops shall be listed separately in the report in alphabetical order.

3. For sake of uniformity, the unit of yield shall be the *ton* for forage crops and sugar beets, the *bushel* for grains and other vegetables and the *pound* for fruits.

4. The values per units of yield shall be the local market price of the crops.

5. *Pastures* shall be included under areas irrigated for crop purposes and the value thereof per acre shall be considered to be the same as that of an acre of hay land on the same farm.

6. Duplicated areas resulting from growing grass and grain on the same land, from raising crops in bearing orchards and from other similar methods of cropping shall be carefully ascertained and deducted.

7. In reporting areas irrigated for other purposes than cropping, there shall be included non-bearing orchards, fall seeded grass fields and fields irrigated for the purposes of cultivation only.

8. There shall be deducted from areas irrigated for other than cropping purposes, areas of crops raised in non-bearing orchards and other similar areas.

9. Owing to the general nature of the information given in this report, the use of decimals shall be reduced to the lowest practicable minimum consistent with reasonable accuracy.

10. When the spaces on one sheet are not sufficient to list all of the different kinds of crops raised on the project an additional sheet should be used and the totals and areas entered on the last sheet.

for various crops, although one farmer seldom raises more than half a dozen things.

Following is the form of crop report or census for each individual water user which has been adopted by the United States Reclamation Service and found to cover the conditions among its twenty thousand or more water users. At first sight it appears somewhat formidable, but in actual use it has been found to be economical and capable of being compiled very quickly by men who are familiar with the locality.

After data for the individual farms have been brought together by the watermasters, canal-riders, or others who have been detailed for the purpose, then the results are compiled in the office of the irrigation manager and arranged somewhat in the shape shown by the following blank, which gives the total acreage in each kind of crop, the unit of yield, and the average, together with the maximum or minimum yield and the value. The crops are listed in alphabetical order for convenience of reference.

In these statistics pastures are included under areas irrigated for crop purposes, and the value per acre is considered to be comparable to that of an acre of hay land on the same farm. This of course increases the acreage and decreases the average value per acre of hay correspondingly.

In the case of duplicated areas resulting from growing grass and grain on the same land during the year or from raising crops in bearing orchards, careful allowance should be made as well as a statement of the duplication.

CHAPTER XV

CONCLUSIONS

Financial Conditions of Irrigation Systems.—The normal condition of all large irrigation projects, during early years at least, is that of extreme financial distress bordering upon bankruptcy. The exceptions to this rule are so notable that they stand as shining examples of what may be hoped. It is well for the irrigation manager to bear this in mind and not become discouraged because of the difficulties which arise from lack of adequate funds to carry out his ideals or even to meet the conditions which he sees are almost imperative. The reason of this financial stringency is not far to seek. It should have been apparent years ago, but was largely ignored or overlooked in the promoting of various large irrigation projects. The causes lie in the fact that farming as a whole is not particularly remunerative and that the average farmer is earning only about day wages. That this is the case is evident from the statistics of the United States Government and from common knowledge of the conditions of the farming communities.

Irrigated farms are no exception to the general rule. There are always to be pointed out striking examples of great success attained by individuals who have carefully used the water, employing skill and good sense, and practicing self-denial. On the other hand, there are many cases of failure, so that the average irrigator is not much better off financially than the farmer in humid lands, although theoretically he should be far more successful.

The question may be asked, "Why do we expect the irrigator to make a larger average profit than the dry farmer?" The reply is that irrigation should mean intensive farming. In a country where the sunshine, the source of all energy, continues through nearly every day of the year, and where the farmer has fairly reasonable control of his water, he should be able to bring these great factors of sunshine and water together and by intelligent application, confined to a small area of land, produce crops with great certainty. In other words, he has within his personal control more of the factors of success than in the case of the farmer in the humid region.

Failure to attain this theoretically possible success is due primarily to lack of capital of the newcomers, many of them starting in with a very small amount of money, say $1,500, to acquire a farm, subdue the soil, stock the place, provide all the necessary improvements, support the family and carry on a business which for assured success requires an investment of at least $15,000. The fact that so many succeed is one of the strongest evidences of the advantage of agriculture by irrigation over the other types of business investment. In fact, looking at it from this standpoint we should be surprised rather than disappointed at the result.

To attain even moderate success under irrigation, requires years of effort, considerable capital, and some experience. It has been assumed in the past that all that it was necessary to do in order to bring about prosperity in an arid region was to put water upon the soil and that thereupon people would flock to cultivate the ground, would raise large crops, and readily repay the investment made. As a matter of fact, it has been found that this simple and direct road to fortune for the promoter and pioneer has many crooks and narrow passages. The leveling and subduing of the soil requires time, strength, and skill. The selection of proper crops and methods of cultivating is a matter sometimes of years of experiment. After improvements have been made on the farm and the soil brought into productive condition, comes the question as to what to do with the products, where to find a market—especially when all of the neighbors are raising an excess of the same crop. At the same time arise the perplexities of various pests and plant diseases. When the pioneer comes to a country it is comparatively free from these—there are few, if any, bugs or blight—but with the development of the country and the bringing in of new plants there come also the pests which accompany these. Under the new conditions many of these flourish with surprising vigor, requiring perhaps years of study to learn what are their natural enemies, what process may be followed to eradicate them or hold them in check.

Ultimately all of these and other questions are solved, but in the meantime, years have elapsed, the interest charges or cost of operation and maintenance have mounted up, and the investment, if made by individuals or corporations, has gradually been dissipated in the effort to keep the works going.

During the first few years after a project has been completed, even the cost of operating and maintaining the works can with difficulty be met by the farmers who are on the ground. Usually only a small part of the total ultimate population has reached the spot, and the few hundred farmers must maintain a system provided for perhaps two or three times as many. These farmers also have brought under cultivation only a part of their farms and must pay for water for say eighty acres out of the products of twenty acres. Each year the payments become relatively easier as more and more land is brought under cultivation and as greater success is attained with the crops; but with an occasional bad year or failure to secure markets, the progress while upward is necessarily slow; far more so, as above stated, than is the growth of the interest charge or of the operation and maintenance expenses. Ultimately these will be met, but in the first few years, perhaps during ten years, the outgo so far exceeds the income that bankruptcy threatens. The condition of the project manager under these limitations and with hundreds of new farmers more or less dissatisfied because they do not know exactly what is proper to expect is indeed not enviable. He can maintain his mental poise only through the knowledge that other people are having as great, if not greater trouble than he is, and that a happy issue is to be expected.

Transfer of Control.—The irrigation project built by a corporation or by the Government is destined ultimately to go into the hands of the water users. The sooner this transfer is made, the better for all concerned if the water users will accept the full responsibility and employ men of large experience. The manager who is thus acting as agent of the original builders must look forward to the time when the water users themselves will exercise more direct control and make such provision as may be necessary towards aiding the water users in appreciating the responsibilities which they should assume.

The manager of the project which has already passed through this period and which is being operated and managed by the water users themselves, has, of course, a somewhat different set of problems, but the manager who, as above stated, is acting for the Government or for an outside corporation, must make a definite effort to bring to his water users a realization of future duties. It is apparent that there cannot safely be any divided control, but as the irrigators acquire more experience there should be put upon them a larger and larger share of definite responsibility. The heterogeneous mass of settlers when first brought together on a new project evidently do not have sufficient acquaintance with each other or with the country, nor experience in business, to handle in a successful manner a large irrigation system. After a few years, however, the social order gradually establishes itself, experience teaches many important facts, and it becomes possible for the irrigators to pass upon certain problems. This they should be urged to do, otherwise they have no conception of the difficulties involved nor appreciation of the efforts and the results attained by the project manager.

The immediate convenience or economies of administration should not be permitted to overweigh the necessity and desirability of giving the settlers experience in these matters, so that when the time arrives when they must operate the canal system as an incorporated body, they can do this upon the basis of actual results. This experience, however, should be obtained in a small way at first, where the outcome will not be destructive. It is better to endure the disappointments or occasional hardships of community management of certain details on a small scale, if by so doing experience is gained which will ultimately lead to the safe operation of the entire system.

There are in the United States few large irrigation systems except those recently constructed by the Government and Carey projects, which are not operated under the coöperative plan by the irrigators, and it is doubted whether it is practicable for an irrigation system to be operated in the United States for any very long period of time on any other basis than directly by the settlers.

Arousing a Social Conscience.—The difficulties which have been experienced in the past in the transfer of responsible control of large irrigation works to the irrigators have grown out of ignorance and lack of development of what may be called a community conscience. An irrigation project completed under the terms of the Reclamation Act, Carey Act, or District Law, is a highly complicated and extremely expensive piece of machinery, comparable to a railroad system or a large manufacturing establishment. If we imagine a large railroad or mill, furnishing occupation to thousands of men, transferred to the control of these men to be operated by them, we have about the condition which exists when a large irrigation project is turned over to the landowners. In some cases there has resulted confusion or even disaster until the entire body of men concerned have been educated through their losses to the observance of certain well-established principles. The problem is to try to avoid these losses and the expensive education which in the past has seemed necessary, by adopting certain precautions and anticipating the dangers which arise from the change.

The successful operation of any large social organization embracing hundreds or thousands of individuals must rest upon well-developed public opinion on the fundamentals. That is to say, no laws or regulations can be adequately enforced in a coöperative organization unless behind these there is a deeply implanted sentiment in their behalf. To illustrate, the conditions of success in stock raising on the public domain may be cited, where organized law and order are at the minimum. The vital condition of life on these vast tracts is the ownership of a horse. No man can conduct the stock business or even live on these vast stretches without a horse. Horse stealing is therefore recognized by the community as a crime against society and punishment is swift and sure. Every man in the community is aroused to effective indignation by reports of stolen horses.

In an agricultural community dependent upon irrigation, the protection of the use of the water is equally vital and the stealing of water undermines the whole social fabric. In old, settled communities, where irrigation has been practiced for generations, any theft of water or interference with established codes, even though unwritten, is punished, the whole public sentiment being against the water thief. It is this which insures the continuance of life, and prosperity of the community, and failure to punish the water thief would undermine the very foundations of the social structure.

In new communities in irrigated regions of the western part of the United States the individuals have come from all parts of the country, few have irrigated in previous years, and there has not been developed that abhorrence of water stealing and of violation of regulations designed to protect the water users. There exists more or less indifference on this point, and in fact a tendency to condone thefts of water from the system built by large corporations or by the Government—as it is a case of the poor man taking from the rich. The laws safeguarding the public use of water are frequently defective and public sentiment has not yet been educated to require strict enforcement even of the laws which are on the statute books. The water hog and the water thief frequently go unpunished, especially if they are men of aggressive personality, accustomed to taking from the public domain whatever they may desire.

This attitude of indifference to the observations of the rules and regulations which have been found vital in older irrigated areas makes the problem of proper control of the works extremely difficult and adds to the dangers of transfer of this control to the entire body of water users. Without a strong central authority no one is willing to come forward to advocate the punishment of the influential neighbor even if he is a notorious water thief. The whole system falls into confusion until through the accumulated losses the community is awakened to its dangers.

Too Much Land.—As has been said before, one of the principal causes of the unfavorable conditions of irrigation systems and of the difficulty of turning over the control and the responsibility to the water users, grows out of the fact that the average man is holding too much irrigated land for his own good or for that of the entire community. During the first two years at least after settlement, the average farmer has nearly double the area of land which he can successfully subdue and cultivate. The tendency on the part of every newcomer is to acquire all of the land possible. His impression is that the land prices will advance, and that he should share in the general prosperity by getting control of as large an area as possible with a view ultimately of selling. In this he is usually disappointed. The prices are apt to decline after the enthusiasm of the boom days of settlement rather than to advance. The majority of irrigators throughout the West have more land than they can successfully use and have purchased this or carried it for so many years that the loss to them is usually larger than can be realized. There are, of course, many notable exceptions to this rule, but this is apt to be the prevailing condition.

The desire of the typical American is to own all of the land which borders on his farm. The irrigator is no exception and if opportunity is given to the newcomer he will generally pay down his last dollar on a first installment of an irrigated tract, securing thus an area twice or three times as large as he can handle. Many of these men must be brought to realize that they are not only crippling the entire community, but ultimately ruining themselves, by the effort to hold these large areas and to pay taxes and water rates on them. They should be induced, as far as possible, to let go the excess land even at a sacrifice, and permit others to come in. By the increased number, due to the low prices of land and its subdivision, there will be a gradual increase of prosperity and of true land values based not upon the speculative or future profits but on the actual crop production.

With the gradual development of the country, the subdivision and sale of excess lands, and with the attention of the individual irrigator confined to a relatively small area, it is possible to produce better crops. By preserving the fertility of the soil, by adding suitable fertilizer, the farmer ceases to be what has been termed a " sapper " of the soil and enters upon an era of prosperity for himself and his fellows.

Better Markets.—With subdivision of the land, with specialization in agriculture, and with growing coöperative efforts, it becomes possible to establish better markets and to obtain better prices for the products of the irrigated area. Irrigation is a business as well as an art and the successful irrigator must first of all be a business man. He follows his vocation primarily for the money he can make and like other business men should endeavor to get the greatest possible returns for the money and labor involved. It is not enough simply to grow crops; they must be so produced as to yield a good profit on the capital invested. To yield this profit they must be handled in such a way as to be placed upon the best market at the time when the best price can be had.

It thus follows, that to succeed, the farmer must be acquainted with every detail of the occupation, both of raising and of marketing the crops, and must strive to prevent all leaks and needless waste. At the same time he must bear in mind that it is a good business principle to spend a dollar whenever he sees that it will come back to him with interest, whether this be in fertilizing his fields, in improving his crops, or in securing better market facilities.

Before the days of good transportation facilities each farming community could control its general business by the application of simple systems of exchange, sale and purchase. With the advent of good transportation facilities, however, no agricultural community can be independent of any other or even of the world in general.

Prices for farm products are fixed by the prices set in large business centers. The markets open to the irrigator are also open to invasion by farmers from other sections who can produce the same products perhaps more cheaply and even better in quality.

Because our farmers have in the past failed to be ideal business men, there has sprung up in this country a class called middlemen who take upon themselves the business which the farmers collectively should control. These middlemen have year by year taken more and more of the gain in transfer from farmer to consumer in return for services rendered. The farmers by combining their resources should be able to sell and realize the full profit on that which they sow and reap.

The farmer who has the good of his community in mind —and this really means his personal advancement and interest—should be willing to join his fellows in securing the best possible market, and thus follow the experience of every other trade or industry in finding strength and profit in union.

Rural Credit.—Every farmer and irrigator at one time or another must borrow money to enable him properly to carry on his business. The difficulty of doing this, especially in a new locality, has added greatly to the hardships of the settlers. Those who live upon the land obtained from the Govermnent, but to which the title is not complete—as evidenced by patent—have little security to offer. Even in the case of patented land many banks or moneyed men will not take this as security.

The interest rates, even if money can be had, are usually very high—nominally 8 per cent.—but the cost of renewals or other additions frequently brings the rate up to 10 per cent. or even 12 per cent. or more. There are few businesses which can afford to pay this rate of interest for any considerable time and the irrigators are no exception. Under these conditions various schemes have been suggested for obtaining money. The conditions in foreign countries have been studied with a view to adapting methods found practicable to the situation in the arid West. There is, however, a wide difference in that in the older countries, where the people have lived for generations, they know each other intimately and are thoroughly informed concerning the peculiarities of every man and his family. They are thus able to unite in using the unrestricted or unlimited credit of the community. In the newer Western states, sparsely populated with people from all parts of the world and with more or less inherited racial and religious antagonism, the possibility of getting together to the extent at least of pledging unlimited personal credit for each other is scarcely conceivable.

There are, however, various systems being worked out for governmental or state assistance, or for united effort. The method which has proved most effective up to the present time is what may be called the "banker-farmer" movement where the bankers or principal merchants united in boards of trade have appreciated the importance of building up the agricultural prosperity of the surrounding areas. These men, individually or collectively, have, furnished money or credit by which high-grade dairy cattle may be purchased at wholesale and sold to the farmers on easy terms, such, for example, as repayment each month of an amount equal to half of the milk check.

Such loans are advanced or made only to farmers who are well known and who have adequate forage and equipment for properly handling a limited number of cows, or for undertaking similar enterprises. The success of this movement is dependent upon the intimate personal knowledge and confidence which exists between the banker or business man lending the money and the farmers, and upon the willingness of the man controlling the credit to use this at a fair rate and for the advantage of all concerned, rather than to seek to obtain the highest rate and to profit by the severe necessity of his client.

In all these transactions, particularly in the initiation of any such system of credit, the irrigation manager necessarily plays a large part, in that his full knowledge of the use of the water, the condition of the farm, and the attitude of the farmer and his family are often decisive in determining whether credit may be extended or not.

Results under Good Management.—It appears from the foregoing that the irrigation manager, if thoroughly competent and alive to his work, is the "king-pin" or point upon which turns much of the success and prosperity of large communities. While he may not be particularly conspicuous, and perhaps if most successful will not be so, yet the careful observer sees that it is through his influence and through the pace which he sets that there results not merely the efficiency and economy of his employees, of the watermasters, canal-riders, and others under him, but also that his influence is far-reaching throughout the entire community. He can make or unmake its prosperity and that without the cause being noticeable on the surface.

The ideal manager has been defined as a man of inflexible integrity, sober, truthful, active, resolute, discreet; of cool and sound judgment, with command of his temper; with courage to resist and repel attempts at intimidation; and possessing a firmness that is proof against solicitation, flattery, or improper bias of any kind. He is a man who takes an interest in his work; is energetic, quick to decide, prompt to act, fair and impartial as a judge on the bench; experienced in his work and in dealing with men, such as comes from maturity of years, business habits, and knowledge of accounts. Men who combine these qualities are not to be picked up every day. Still they can be found. They are greatly in demand, and when found they are worth their price, or rather they are beyond price and their value cannot be estimated in dollars.[1] The results which flow from activities of men of this kind are beyond measure, not merely in the financial sense, but in the still higher qualities which lead to the growth and development of strong and healthy communities and which mold and bring forward the men and women of high character who are the strength of the nation.

[1] See Chief Engineer Sterling's Report to the Mississippi Levees Commissioners.

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